

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

MISSISSIPPI RIVER COMMISSION

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PLANS FOR  
THE IMPROVEMENT OF THE ST. JOHNS RIVER  
JACKSONVILLE TO THE ATLANTIC OCEAN  
MODEL INVESTIGATION



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TECHNICAL MEMORANDUM NO. 2-244

U.S. WATERWAYS EXPERIMENT STATION  
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VICKSBURG, MISSISSIPPI

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1.

PLANS FOR THE IMPROVEMENT OF THE ST. JOHNS RIVER

JACKSONVILLE TO THE ATLANTIC OCEAN

MODEL INVESTIGATION

SYNOPSIS

This memorandum is a comprehensive report on the St. Johns River model study, which was conducted by the Waterways Experiment Station for the Jacksonville District, Corps of Engineers, during the period August 1945 through September 1946. The investigation was authorized by the Chief of Engineers, U. S. Army, on 25 May 1945.

The model study was concerned with the determination of: (a) the effects of dredging the ship channel of the St. Johns River from Jacksonville to the ocean, from a depth of 30 ft to 34 ft at local mean low water; (b) the most satisfactory of three proposed alignments for a cutoff between Dames Point and Fulton for purposes of navigation; (c) the effects of deepening the channel and constructing the cutoff upon the Jacksonville harbor as a whole; and (d) the additional works that would be desirable or necessary to obtain the best results from the cutoff finally selected.

The tests herein reported were made on a hydraulic model of the fixed-bed type which reproduced approximately 110 miles of the St. Johns River and all of its major tributaries from the ocean to Welaka, Florida. Tides and tidal currents were reproduced by means of an automatic device constructed for that purpose.

After the model had been adjusted and its similarity to the



prototype verified, tests were made of a curved cutoff, a straight cutoff, and a modified straight cutoff. Studies were made to determine the effects of each plan from the viewpoints of navigation, possible bank erosion, and stagnation of certain areas; a test was also made to determine the feasibility of realigning and lengthening Wards Bank training wall near the mouth of the river to reduce shoaling in that area.

The results of model tests indicate the following:

- a. The straight cutoff with a wide flare at its downstream end (Plan B-5) appears to be the most satisfactory alignment tested. This cutoff would probably be more costly to build than either of the others; its construction would be more difficult; and its right-of-way harder to procure. If its merits should be outweighed by these considerations, the modified straight cutoff (Plan C-1) appears to be more desirable than the curved one (Plan A-1).
- b. Provision must be made to reduce the cross currents from Mill Cove and Back River into the cutoff. If a dike is constructed south of the cutoff (Plans A-1, B-1, and C-1), cross currents will result at Brills Cut. If a dike is placed parallel to Brills Cut (Plan A-3), flow into Drummonds Creek Range will be satisfactory, but the Mill Cove area will become stagnant. A study made of a 100-ft opening 10 ft deep in the dike south of the cutoff (Plans C-6 and C-7) showed that such an opening would allow tidal circulation in the Mill Cove area but that high current velocities through the opening would render it dangerous for navigation except at or near times of slack water.
- c. The plan of elongating Wards Bank training wall and moving it to a position parallel with Bar Cut Range (Plan D-1) could be expected to alleviate materially the shoaling condition along the west end of the north jetty.
- d. Other than local effects in the vicinity of the proposed cutoff, none of the plans tested appeared to change appreciably the range of tide, the velocities of tidal currents, or the movement of the salt-water wedge throughout the river.

## PART I: INTRODUCTION

### The Prototype

1. The St. Johns River rises in Brevard County in east-central Florida, flows northerly 257 miles to Jacksonville and thence easterly 28 miles to the Atlantic Ocean, a total distance of 285 miles. The watershed averages about 40 miles in width and has an area of about 8160 square miles. The river may be considered to consist of three distinct sections. The upper section of the river, from its source to Palatka, a distance of 202 miles, is narrow and sluggish, flowing through the system of large lakes which characterize its upper reaches. The second or middle section from Palatka to Jacksonville, a distance of 55 miles, consists of a long lagoon varying from 1/4 mile to 3 miles in width. The third section, from Jacksonville to the ocean, a distance of 28 miles, is in some respects a continuation of the second section; in this lower section, however, the river has been turned to the uses of navigation by means of training walls, jetties, dikes, dredging, and such other works as are characteristic of a modern deep-draft navigation facility. It was with this lower section of the river that the model study was chiefly concerned.

2. Of the 28-mile reach between Jacksonville and the ocean, 23 miles have been dredged to afford a channel 30 ft deep at local mean low water. The remaining 5 miles have a natural depth equal to or exceeding the depth of the dredged channel. The channel from Jacksonville to the ocean follows the natural course of the river, which is extremely sinuous, the total deflection in this reach being  $884^{\circ}$ .

3. Of the total deflection of the channel between Jacksonville and the ocean, Dames Point Bend accounts for  $124^{\circ} 15'$ . This bend has a radius of 2000 ft and a length of 4250 ft. Dames Point, which is a relatively high peninsula with several buildings and a heavy growth of underbrush and tall trees upon it, obstructs the view of ships rounding the bend. At strengths of both ebb and flood tides, currents around the bend are particularly swift and masters are forced to slow their vessels and proceed cautiously to prevent colliding with ships coming in the opposite direction, or running aground to avoid such collision. These factors make Dames Point Bend the most hazardous reach in the navigable portion of the river. The same difficulty exists at the Fulton-St. Johns Bluff Bend, although to a lesser extent. Such obstacles result in considerable lost time, since ships arriving at the bar after nightfall, or preparing to put out from port at such time, are forced to lie at anchor until daylight. These navigation hazards, and others of less importance, have cast doubt upon the adequacy of the existing navigation channel to serve the port most efficiently.

#### The Problem

4. Jacksonville is the chief seaport of northern Florida and of a portion of southern Georgia. Being 28 miles above the mouth of the St. Johns River, it depends upon the ship channel for its sea-borne commerce. Statistics show that the magnitude of this commerce has consistently increased, and indications are that it will continue to do so. This situation has focused the attention of shipping interests on the weaknesses inherent in the present navigation channel from the

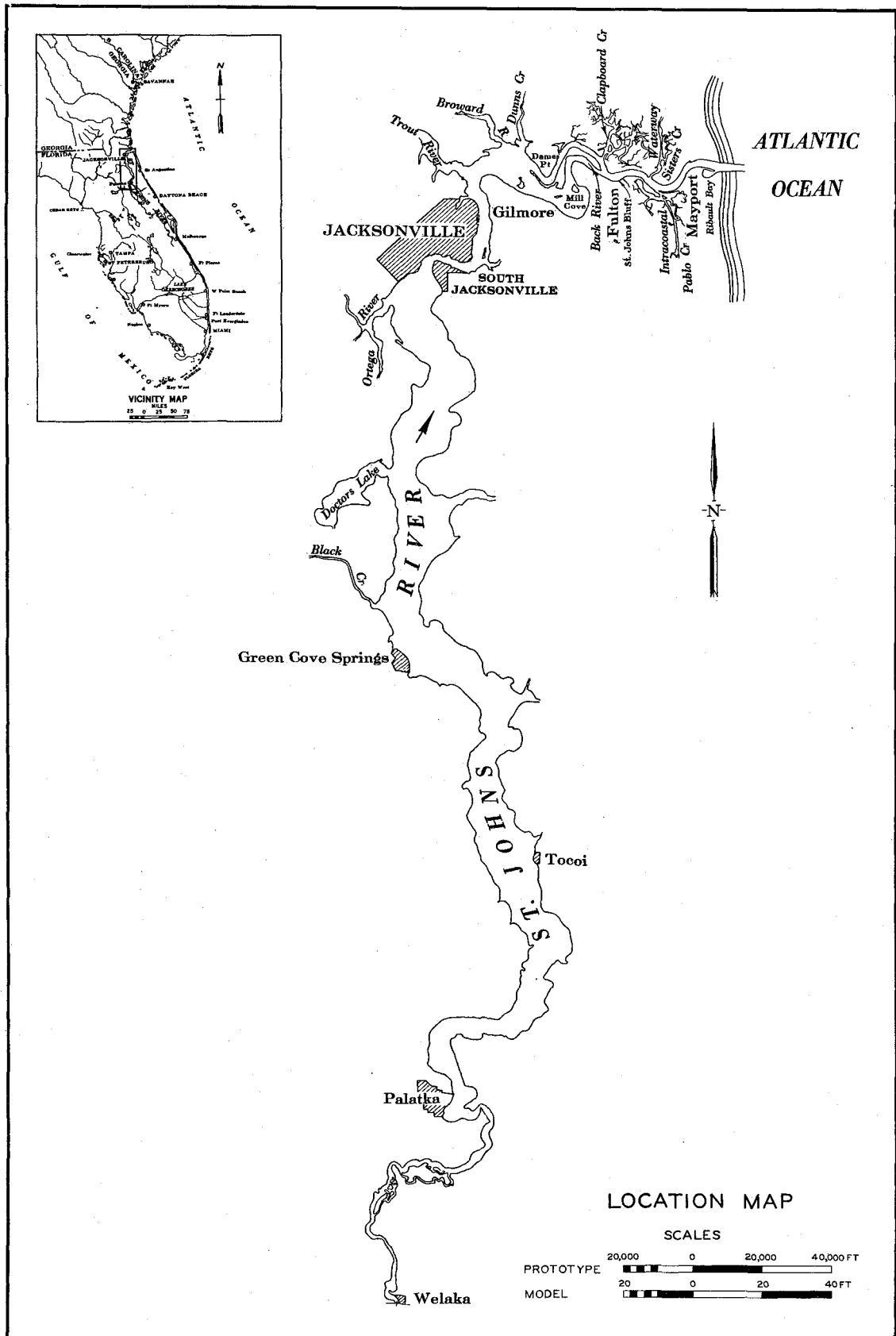


Fig. 1

city to the Atlantic Ocean.

5. The location map on figure 1 illustrates the extreme sinuosity of the river from Jacksonville to the ocean. To reduce navigation hazards of the bends at Dames Point and St. Johns Bluff, consideration has been given to a proposed cutoff to extend from Dames Point to some point in the river near Fulton. Certain other improvements, including deepening of the channel from Jacksonville to the ocean from 30 ft to 34 ft at local mean low water, and widening of Terminal Channel from 400 ft to 590 ft, have been proposed. During the study of these plans, recourse was had to hydraulic model tests for resolution of the following problems: selection of the most satisfactory alignment for the proposed cutoff; determination of the advantage of such a cutoff and of other desired improvements; and determination of the secondary improvements that would be desirable or necessary for the most satisfactory functioning of the cutoff.

#### Authorization of Model Study

6. Request for a model study was initiated by the District Engineer, Jacksonville District, in a letter dated 9 May 1945, subject: "Request for model study of the St. Johns River, Jacksonville to the ocean"; authority was granted by the Chief of Engineers in second indorsement thereto dated 25 May 1945.

#### Securing and Preparation of Basic Data

7. When plans for the model study were undertaken, it was found that insufficient prototype data were available upon which to base the

adjustment and verification of the proposed model. Therefore, a survey was organized by the Jacksonville District in August 1945 to obtain the necessary information. A brief description of the data obtained follows.

### Salinity and current velocity data

8. Stations 1-10 (figure 2) were established between the ocean and Palatka for the purpose of making observations of salinity and current

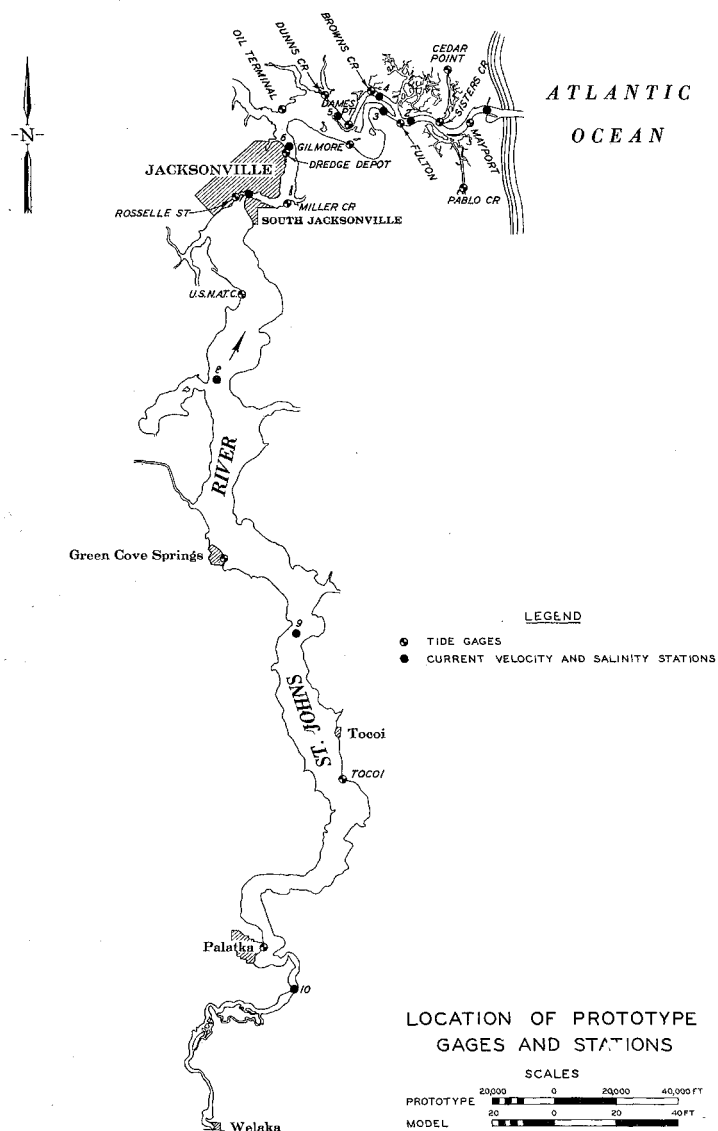


Fig. 2

velocity. Such observations were made during three runs of two days each, for 13 hr each day, to obtain data for a neap, average, and spring tide. Observations were made upriver from Jacksonville on the first day, downriver from the city on the second day, and at Jacksonville (station 7) on both days. Hourly salinity observations were made 3 ft from the bottom and at each 6-ft interval of depth to the surface. Half-hourly current velocity observations were made at each one-tenth interval of the depth. The salinity of all samples obtained was ascertained by hydrometers aboard ship; all top and bottom samples and slack-water samples were retained, and their salinity was determined by chemical titration as a check. The data so obtained were prepared by the Experiment Station for model use.

#### Tidal data

9. During the course of the entire observation period, tidal heights were automatically recorded at the tidal stations shown on figure 2.

#### Field data used for model adjustment and verification

10. It was anticipated that proposed improvement plans would be tested for spring, average, and neap tide conditions; however, it was later decided to use average conditions only in the model. Consequently, field data obtained for spring and neap tide conditions are not presented in this report; data pertaining to tidal heights, current velocities, and salinity for average tide conditions are discussed more fully in Part III, and presented on plates 1-16.

Liaison and Personnel

11. During the course of the investigation, several visits were made to the Experiment Station by the District Engineer and his representatives, and conferences were held by representatives of the South Atlantic Division, the Jacksonville District, and the Experiment Station. Engineers of the Experiment Station actively connected with the model study were Messrs. E. P. Fortson, Jr., G. B. Fenwick, H. B. Simmons, B. C. Keene, and T. J. Kinzer. Semi-monthly progress reports were made to the District Engineer, and interim reports were submitted at the conclusion of each of the several phases of the study.

Related Model Study

12. A model study of plans for prevention of pollution in the St. Johns River at Jacksonville was conducted on the St. Johns River model for the City of Jacksonville in November 1946. A detailed report of the study was submitted to the City of Jacksonville in February 1947, a resume of which is appended hereto.



## PART II: THE MODEL

Description

13. The St. Johns River model was a scale reproduction of approximately 68 square miles of the Atlantic Ocean and approximately 110 linear miles of the river. The area reproduced included the extensive tidal tributaries between the ocean and Jacksonville, Back River, Mill Cove, Doctors Lake, and portions of Broward River, Trout River, and Black Creek (see figure 1 for general layout).

14. The model was of the fixed-bed type, all channel and overbank areas being molded in concrete. Overbank areas were molded to an elevation 10 ft above mean low water at Mayport, and channel areas were molded in conformity with hydrographic surveys made by the Jacksonville District and the U. S. Coast and Geodetic Survey. Provisions were made to reproduce the river discharge at Welaka and the tides and tidal currents in the ocean and river.

Scale ratios

15. The model was constructed to linear scale ratios, model to prototype, of 1:1000 horizontally and 1:100 vertically. The salinity scale ratio used was 1:1. Other scale ratios, computed from linear scale ratios, according to the Froudian relationship, were as follows:

Velocity	1:10
Time	1:100
Discharge	1:1,000,000

Model appurtenances

16. Automatic tide reproducer. The rise and fall of the tide and

the accompanying tidal currents in the model river system were obtained by reproducing the proper rise and fall of the tide in the model ocean. This was accomplished by means of an automatic tide reproducer situated in the model ocean. Figure 3 is a schematic diagram of the tide reproducer used on the St. Johns River model. The machine consisted essentially of the following components: (a) a main header sloping from the model to a near-by water-supply sump; (b) a pump supplying through a separate line a constant flow from the sump into the main header; (c) a motorized, commercial rising-stem valve installed in the main header at a point about 3 ft toward the sump from the entrance of the pump line into the main header; and (d) an automatic control apparatus located within the model for regulating the operation of the valve by means of

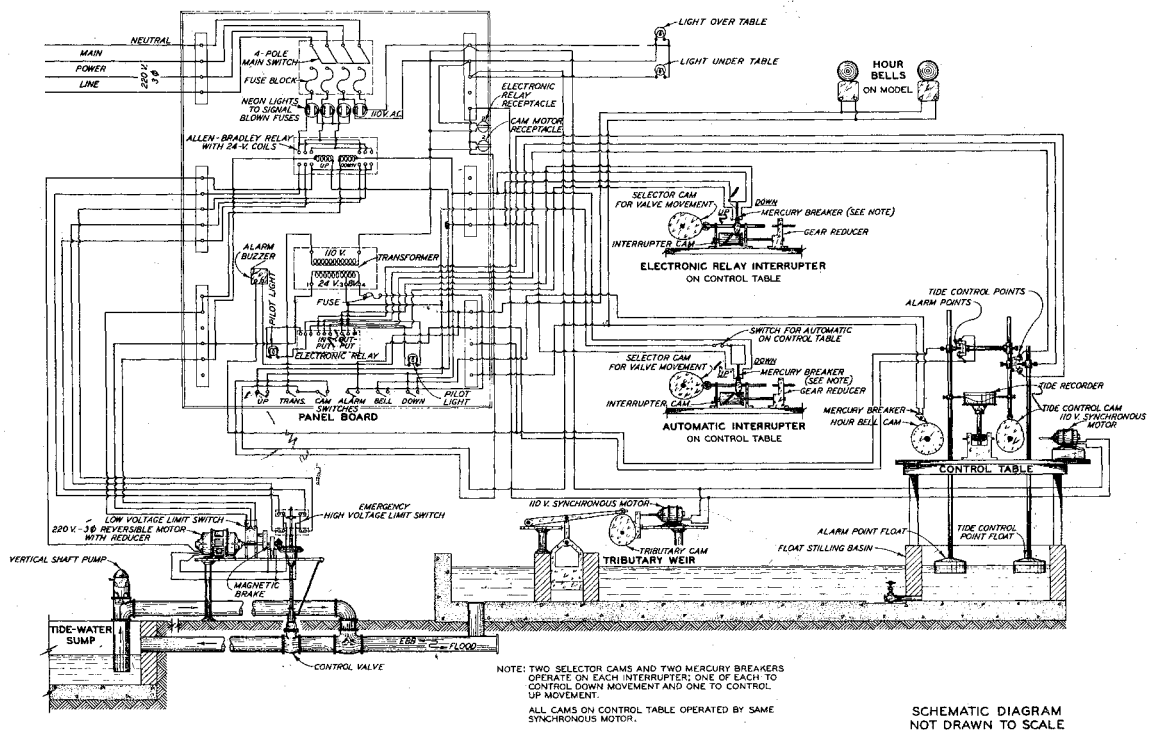


Fig. 3. Tide control mechanism

a system of floats and electric contacts. A complete closure of the valve would divert the entire output of the pump into the model and thus create a rapidly "flooding" tide; a complete opening of the valve, on the other hand, would allow not only the entire output of the pump but also gravity flow from the model to return to the sump, and thus create a rapidly "ebbing" tide. It may be seen, therefore, that by controlling intermediate valve openings, any desired rate of ebb or flood could be reproduced in the model.

17. Automatic control apparatus. The automatic tide control apparatus was equipped with a cam cut to a polar plot of the prototype mean tide rotated by an electric motor at a speed determined by the computed time scale. Riding vertically upon this cam was a follower bearing a pair of electric contacts, one above the other, which rotation of the cam caused to rise and fall in accordance with the plotted tide curve. A third contact, placed between this pair of contacts with 0.001-ft clearances above and below, was mounted upon a rod riding a float in the control pit, which was freely connected with the model ocean by means of pipes. Thus, whenever the water-surface elevation in the model was in error equal to or greater than the clearances between the contacts, the circuit closed, and movement was given to the valve. Anticipating the need for a certain amount of valve movement to produce the necessary change in the direction of the movement of the water surface at low tide and high tide, a secondary circuit was used to impart a predetermined motion to the valve.

18. Automatic tide recorder. The automatic control apparatus just described was equipped with a recording device which inked on a roll of

paper a continuous record of the model tide curve, superimposed upon the prototype curve being reproduced. The prototype curve was inked by a pen riding the plotted cam, while the model curve was superimposed by a pen riding on a float in the control pit. This feature permitted a visual check on the accuracy of the model tide reproduction at all times.

19. Intracoastal Waterway control gates. It was not necessary to reproduce extensive reaches of the Intracoastal Waterway in either direction from the St. Johns River. In order to reproduce the tidal phenomena in the sections which were incorporated into the model, movable vertical gates were installed at the ends of the sections. Each of these gates was moved by an arm riding a cam which was driven by a motor synchronous with the motor driving the automatic control mechanism. The necessary vertical movement of the gate was plotted on the cam. In order to create an ebbing tide, water was introduced at the bottom of each of the pits which terminated the two sections of the waterway reproduced. Overflow was returned to the water-supply sump.

20. Fresh-water inflow weir. The necessary fresh-water inflow was introduced at the upper extremity of the model river through a California pipe weir supplied from a constant-head tank.

#### General Test Procedure

21. Following construction of the model, the study thereon was divided into three separate but interrelated phases: (a) model verification, (b) establishment of a base test, and (c) testing of the various plans of improvement. Model verification consisted of a cut-and-try process of adjusting the model to reproduce prototype phenomena and to

establish proper operating technique to ensure consistency in the testing program (this phase is described in detail in Part III of this report). The operating procedure during the verification phase was then maintained during the base test and all subsequent tests of proposed plans of improvement.

#### Model data

22. Tidal heights. Tidal heights were measured at half-hourly intervals of the tidal cycle by means of gages graduated to 0.001 ft. The location of these gages may be seen on figure 4.

23. Current velocities. Current velocities were measured at half-hourly intervals of the tidal cycle at top, middepth, and bottom at all stations shown on figure 4 except 8, 9 and 10. A small velocity meter was used to obtain velocity measurements at stations 1-7; measurements at stations 8-10 were obtained by timing the movement of a float over a measured range.

24. Salinity. Salinity samples were taken at top, middepth, and bottom at the stations shown on figure 4. The salinity of each sample was determined by the chemical titration method.

25. Flow-pattern data. The flow-pattern photographs presented in this report are vertical, four-second exposures of confetti moving on the model river, the water having been darkened with dye to provide a suitable background for the confetti streaks. Pictures showing the entire length of any of the three cutoff alignments are mosaics of three separate pictures, since it was impossible to cover the entire problem area in one exposure.

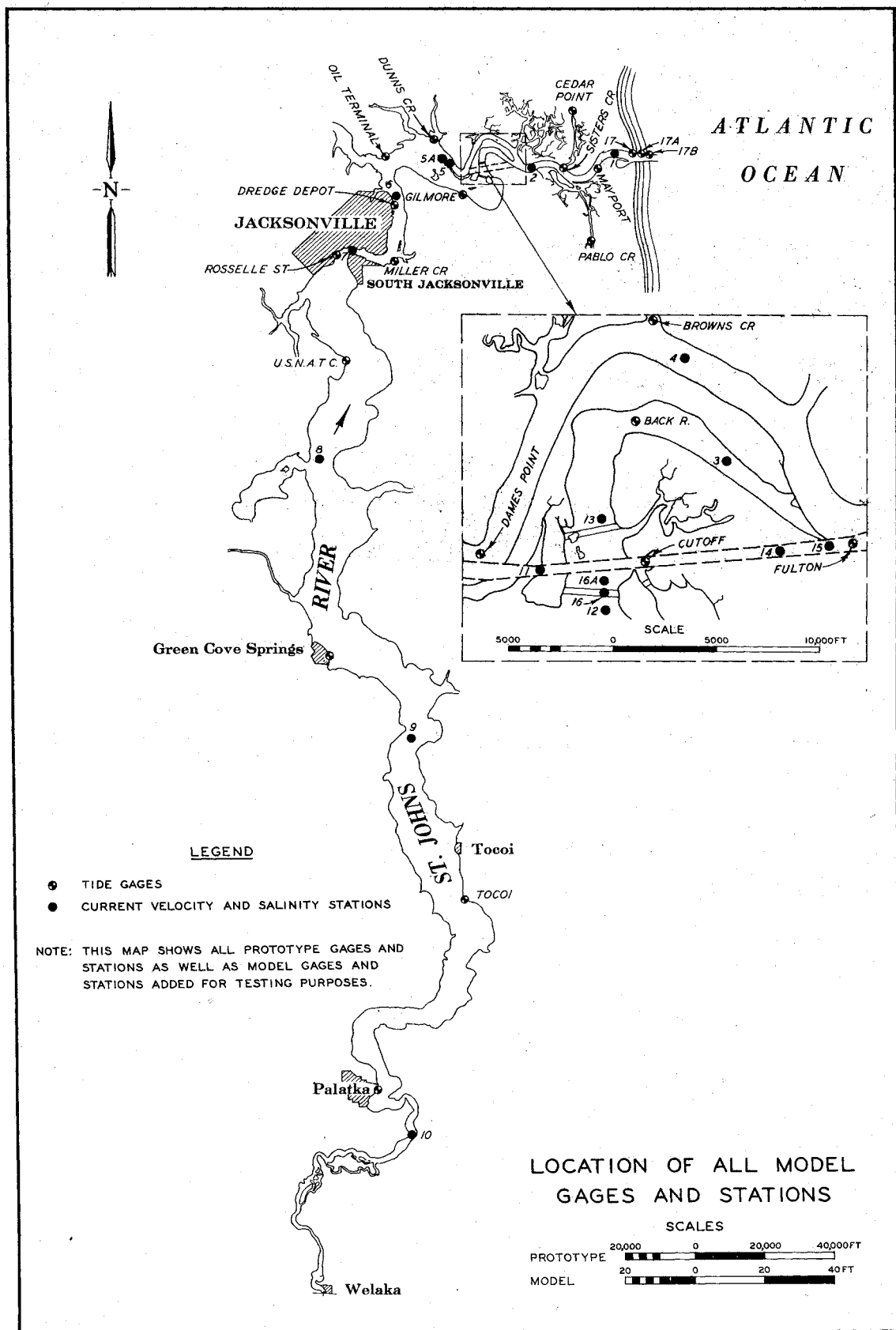


Fig. 4

## PART III: VERIFICATION OF THE MODEL

26. The value of a model study of the type under consideration is dependent upon the ability of the model to reproduce, with a reasonable degree of accuracy, hydraulic phenomena of its prototype. It is essential, therefore, before model tests of improvement plans are undertaken for the purpose of predetermining the effects of such plans upon the prototype, that the required similitude between model and prototype be established. In the case of the St. Johns River model, in which the predominating force was that of gravity, the scale ratios were computed in accordance with Froude's law (paragraph 15). It was then necessary to adjust the model so that prototype hydraulic phenomena would be reproduced to the computed scales. The phenomena which the St. Johns River model was required to reproduce were tidal heights, current velocities and directions, and action of the salt-water wedge in the river.

ProcedureTidal heights

27. The adjustment of the electro-mechanical tide reproducer consisted of adjusting the cams which moved the mercoid switches (figure 3) on the interrupter drums. This was a cut-and-try process, which had as its purpose the adjustment of the vertical fluctuation of the model ocean elevation through a tidal cycle. When this was accomplished, the river tides were adjusted by adding roughness to the river bottom, first in the form of stucco and then of small rocks, to simulate the roughness factor in the natural stream bed. This was an empirical process of adding

and removing roughness until the prototype tidal heights were reproduced to model scale at each of the model gages. The tide reproduced in the model was the prototype tide of 20 and 21 August 1945, and was of approximately mean range.

#### Current velocities

28. When the model had been adjusted to reproduce the proper tidal heights at all gages, current velocities, which vary as the tidal range, were found to be correct except for a few instances which were corrected by minor changes in roughness. Model measurements were made in accordance with the method described in paragraph 23 above, at the stations shown on figure 2.

#### Salinity

29. The salinity of the model ocean was maintained at 30,000 parts per million, the approximate salinity of the Atlantic Ocean adjacent to the mouth of the St. Johns River at the time prototype data were obtained. Since the salt water penetrated only as far upstream as Jacksonville, a movable block was placed across the river at the upper extremity of the gut at Jacksonville, and another in the vicinity of Mayport. At the end of each day's run the water above the upper block was still fresh and was retained in the model for further use; water between the two blocks was fresh at the top and salty at the bottom and was wasted; and water below the lower block was returned to the salt-water sump and its salinity checked and readjusted for further use. At the beginning of each day's run, the elevation of the water above the upper block was adjusted; the river between the two blocks was filled to the proper elevation with



fresh water; and, after the elevation of the ocean had been adjusted, the blocks were removed and the tide machine started. The model was then allowed to run through several successive tidal cycles, to effect proper adjustment between fresh water and salt water in the lower reaches of the river, before observations of the phenomena under consideration were made.

#### Fresh-water discharge

30. Discharge data used for adjustment and verification purposes were provided by the U. S. Geological Survey. A discharge of 11,000 cfs was found to be applicable to the period during which prototype observations of tides, current velocities, and salinities were obtained. The combined discharges of the St. Johns River, the Oklawaha River, and north and south forks of Black Creek were introduced into the model at Welaka, the upper extremity of the model river. Model tidal heights and current velocities were correctly reproduced with the above discharge, but it was found that salinities in the model were slightly high. This apparent discrepancy was attributed to the fact that the season during which data were taken was one of unusually high precipitation, and the runoff from the marshes and tributaries was not included in the discharge measurements used. It was estimated that an additional freshwater flow of approximately 6,000 cfs entered the St. Johns River from those tributaries; therefore, the river discharge was increased to 17,000 cfs. Under this condition, salinity measurements made at top, middepth, and bottom at all stations were reasonably similar to those made in the prototype. This increased discharge had no appreciable effect on tidal heights or current velocities throughout the model.

### Results

31. The degree of accuracy with which the model reproduced prototype tidal heights, current velocities, and salinity may be seen on plates 1-16. Model tidal heights from Mayport to the U. S. Naval Air Training Station gage appear to be uniformly consistent with observed prototype tidal heights, the greatest discrepancy being a difference in range of 0.3 ft at Fulton and slight differences in phase at Gilmore and Dunns Creek. From the U. S. Naval Air Training Station gage to the Palatka gage, model tidal heights appear slightly high; however, the correct tidal range was reproduced at these gages. Model current velocities at all stations correspond closely with those of the prototype, and model salinities check those of the prototype within a reasonable degree of accuracy.

### Discussion of Results

32. The similarity between hydraulic phenomena in the model and the prototype was sufficiently close for all purposes of the model study. It is believed that the graphs showing tidal heights in the prototype and in the model demonstrate conclusively the ability of the model to reproduce with reasonable accuracy the prototype phenomena involved, and to predetermine the effects of improvement plans upon the natural river.

33. The necessity of using a higher discharge to verify the ability of the model to reproduce the salt-water phenomena observed in the prototype, than that used to verify tidal heights and current velocities, may be readily demonstrated. It was not at first anticipated that

fresh-water discharge from minor tributaries between Welaka and the ocean would be sufficient to affect the phenomena observed in the model, since normally such discharge is negligible. However, as previously stated, prototype data were obtained when precipitation was unusually high. It was considered impracticable to introduce the correct discharge in each small tributary; therefore, the combined discharge of all tributaries was introduced at Welaka, which procedure restored the model salt-water wedge to its proper prototype limits.

## PART IV: NARRATIVE OF TESTS

34. After the verification procedure had signified the ability of the model to reproduce with reasonable accuracy tidal heights, current velocities, and salt-water movements observed in the prototype under corresponding conditions, a series of tests was made on the model to pre-determine the effects of the proposed plans of improvement if installed in the prototype. The basic plans tested were, in general, as follows: (a) dredging of the ship channel from 30 ft to 34 ft at local mean low water; (b) installation of a gently curving cutoff in the river from Dames Point to Fulton; (c) installation of a straight cutoff in the same reach; (d) methods of preventing cross currents out of Mill Cove into the ship channel without stopping the tidal circulation or navigation therein; and (e) elongation of Wards Bank training wall and moving it into a position parallel with Bar Cut Range. Several modifications of the basic plans were developed and tested during the course of the model study.

Base Test

35. It was considered desirable to compare the results of the various improvement plans in the model with data representing normal conditions in the unimproved river, in order to isolate the effects of such plans. Therefore, a base test, or test of existing prototype conditions, was made prior to the testing of the various improvement plans. Test operating procedure for the base test consisted of reproduction of a mean tide in the model ocean and introduction of a normal fresh-water

discharge of 4,000 cfs (mean annual discharge for the years 1938 through 1942) into the upstream end of the model. Model data were obtained at a sufficient number of stations to provide a basis of comparison for the results of subsequent tests of improvement plans (see photographs 1-4).

### Model Operating Procedure

36. After the base test had been established, the model ship channel from Jacksonville to the Atlantic Ocean was dredged to a depth of 34 ft at local mean low water, with the exception of the reach between Dames Point and Fulton which was intercepted by each of the several cutoff alignments. This condition remained unchanged during the tests of all improvement plans.

37. Testing of the various plans of improvement consisted of installing each respective plan in the model, starting the tide control and setting the river discharge weir, allowing the model to run for several tidal cycles to effect proper adjustment of the salt-water wedge, and then making such observations of tidal heights, current velocities and directions, and salinity as were required for analysis of the effects of the plan of improvement under consideration.

### Plan A

#### Description

38. The features peculiar to Plan A included the curved cutoff between Dames Point and Fulton shown on figure 5. This cutoff departed from the St. Johns River opposite Dames Point, crossed Back River, and reentered St. Johns River at the mouth of Back River opposite Fulton.

The cutoff had a depth of 34 ft at local mean low water and a bottom width of 500 ft. Operating conditions for Plan A were the same as for the base test. Plan A was tested first with a narrow flare at the upper end of the cutoff (figure 5), then with a wider flare at the upper end.

### Results

39. No measurable differences in tidal heights and current velocities for the wide and narrow flares of the cutoff entrance were observed; hence, tide and velocity data are presented for the wider flare only. Since flow distribution at the upstream end of the cutoff was slightly affected, flow-pattern photographs are presented for both conditions. Plan A tidal heights are shown on plates 17-21; current velocities on plates 22-29; and salinity on plate 30. Flow patterns for Plan A with the wide flare at the upstream end are shown on photographs 5-9, and for

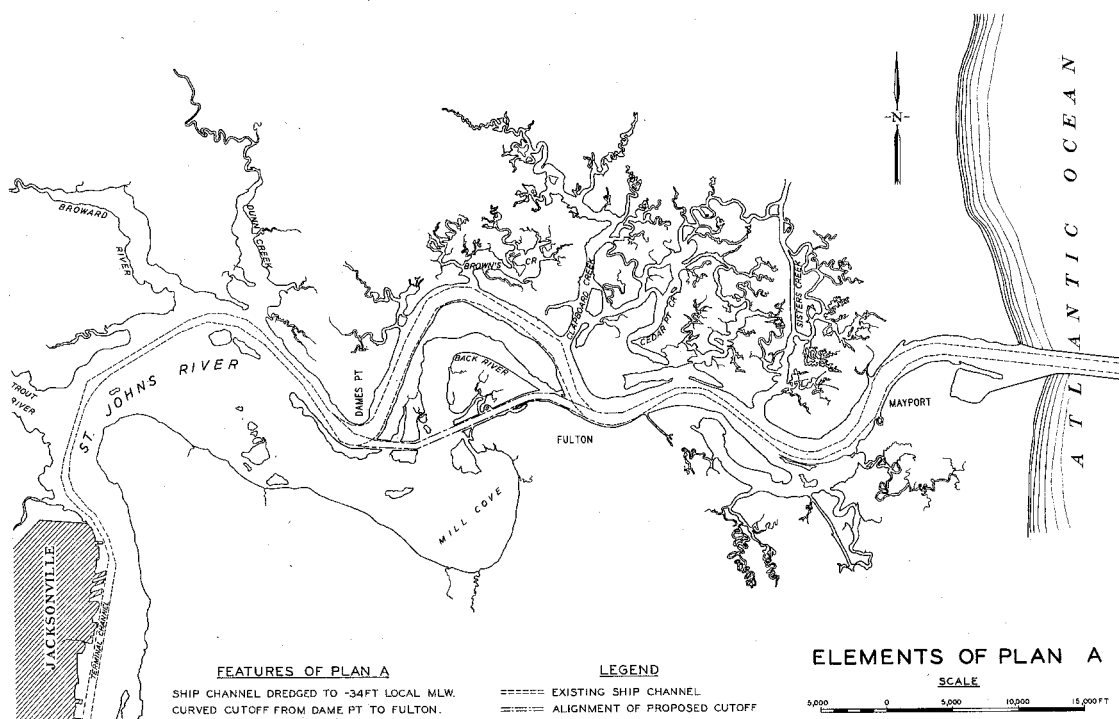


Fig. 5

the narrow flare are shown on photographs 10-12. Installation of Plan A in the model caused decreases in tidal range of 0.3 ft at Sisters Creek, 0.6 ft at Fulton, and 0.2 ft at Browns Creek. The phase of the tide at the Gilmore gage in Mill Cove was changed by approximately three-fourths of an hour, and the tidal range was increased by 0.5 ft. The most significant of the tests results were: (a) the flood currents failed to pass through the entire length of the cutoff, the flow being diverted into Mill Cove at the point of the intersection of the cutoff with Back River; (b) during flood tide, currents flowed from Back River across the cutoff into Mill Cove (photograph 7); (c) the cross currents caused by the ebbing tide out of Mill Cove into the cutoff appeared worst during the two hours following high-water slack. Observations of the movement of dye indicated that the current velocity was fairly uniform throughout the cross section of Back River; and, since the depth of Back River at its intersection with the cutoff is 22 ft, the component of the cross current against a ship moving in the cutoff would probably be dangerous rather than merely inconvenient. The behavior of the cutoff was reflected in the current-velocity measurements in its vicinity. Current velocities at station 5 (for location see figure 4) were considerably reduced. Those at station 11 were considerably lower than those at station 14, indicating that the water passing station 14 on flood tide was diverted from the cutoff before reaching station 11. Comparison of Plan A current velocities at station 4 with those of the base test shows that the installation of Plan A reduced the current velocity due to the interception of that reach of the river by the more efficient cutoff channel. A study of the flow-pattern photographs indicates that the

pattern of ebb flow into the upper entrance of the cutoff was slightly better for the narrow flare than for the wide flare, currents in the latter case showing a tendency (indicated by confetti streaks) to swing to the north and attack the point between the cutoff and the intercepted reach of the river. The cutoff caused a slight decrease in maximum salinity at the Fulton end and a slight increase from the upstream end of the cutoff to the vicinity of Dredge Depot (see plate 30). It appeared that the more efficient channel effected a more uniform slope of the profile of maximum salinity.

### Plan A-1

#### Description

40. Plan A-1, the elements of which are shown on figure 6, reproduced the Plan A cutoff (with the wide upstream flare) with the

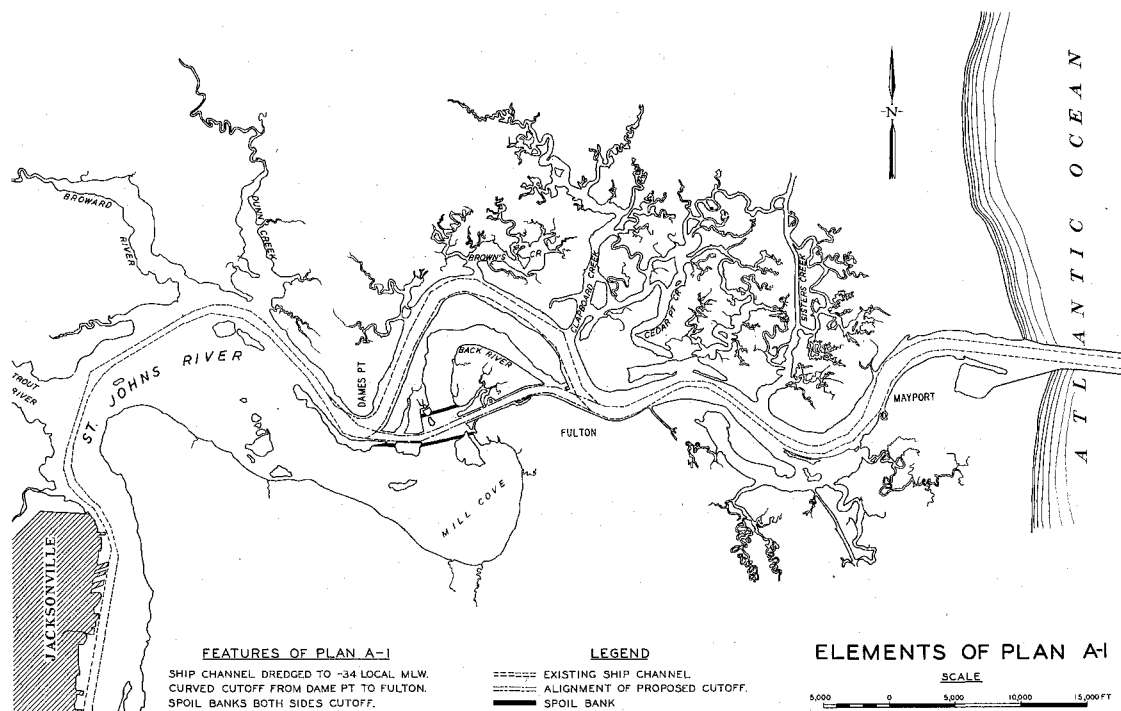


Fig. 6



addition of spoil dikes across Back River on each side of the cutoff to eliminate the hazardous cross currents which had been observed there during the tests of Plan A. The operating procedure for the test was the same as for the base test. Velocity station 5-A was added during this test for the purpose of observing the velocity of currents passing between the spoil dikes at station 5 in Brills Cut.

### Results

41. Since no appreciable change from base-test conditions was observed for Plan A-1 in that portion of the river from Jacksonville to Welaka, no data are presented for that reach. Tidal heights for Plan A-1 are shown on plates 31 and 32, current velocities on plates 33-40, flow patterns on photographs 13-17, and salinity on plate 30. The significant results of Plan A-1 were: (a) the hazardous cross currents from Mill Cove and Back River were eliminated by the addition of the dikes; (b) current velocities at stations 5 and 11 were increased over those of Plan A; (c) the tidal range at Gilmore in Mill Cove was decreased from its base-test proportions by 0.3 ft; (d) flow out of the Mill Cove area into Brills Cut created a cross current into the navigation channel at the hour after high-water slack; however, observations by means of dye indicated that cross currents at this point were shallow, and while they would be inconvenient for navigation, would probably not be hazardous; and (e) a slight increase in current velocities at station 7 was observed, but there was no appreciable change in tidal range at Rosselle Street gage. The effect of the spoil dikes on the maximum salinity profile was negligible (see plate 30).

Plan A-2Description

42. Plan A-2 (figure 7) reproduced all the elements of Plan A-1 except the dike across Back River south of the cutoff. It was the purpose of this plan to ascertain whether the hazardous cross currents in the cutoff at its intersection with Back River would be ameliorated by a dike across Back River north of the cutoff only.

Results

43. Since no significant change above Jacksonville resulted from the installation of Plan A-2, no data pertinent to that reach of the river are presented. Tidal heights for Plan A-2 are shown on plates 41 and 42, current velocities on plates 43-49, and flow patterns on

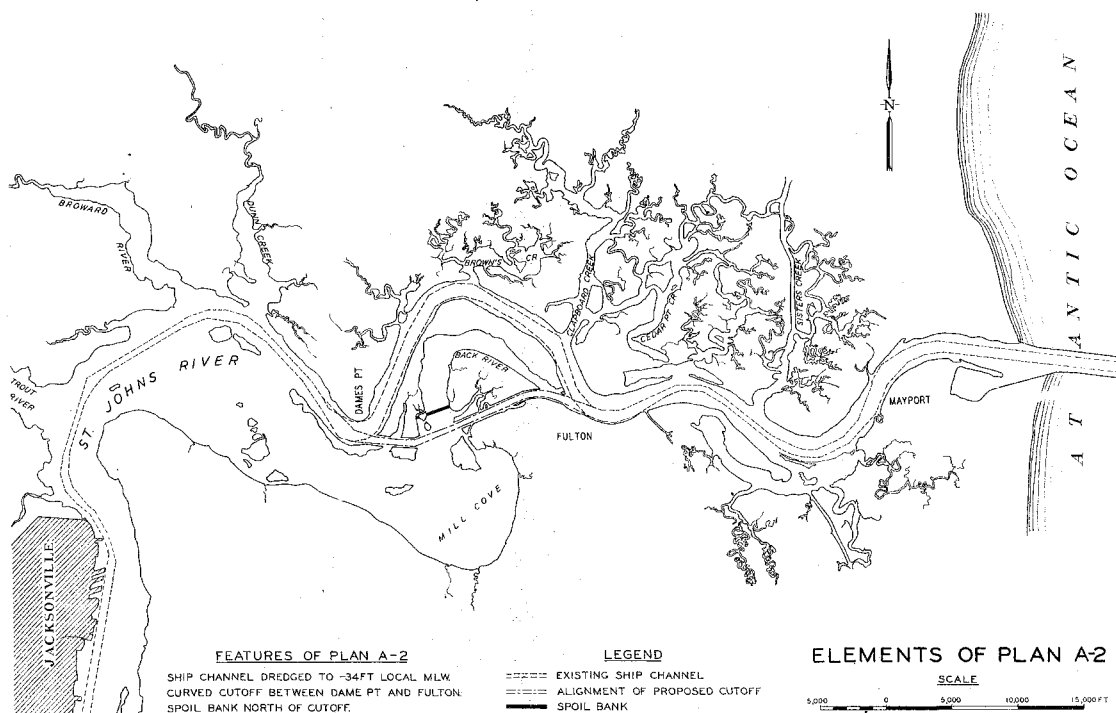


Fig. 7

photographs 18 and 19. The principal effects of this plan were: (a) the tidal range in Mill Cove was restored to approximately its Plan A proportions; (b) current velocities at stations 5 and 11 were reduced to approximately their Plan A proportions, the top velocity at station 11 showing the greatest reduction; (c) while it eliminated the flow of flood currents from Back River into Mill Cove directly across the cutoff channel, it did not ameliorate ebb flow out of Mill Cove into the cutoff after high-water slack. The maximum salinity profile for this plan was the same as is shown on plate 30 for Plan A-1

### Plan A-3

#### Description

44. The elements of Plan A-3 are shown on figure 8. This plan reproduced all the features of Plan A-1 with the addition of dikes in the

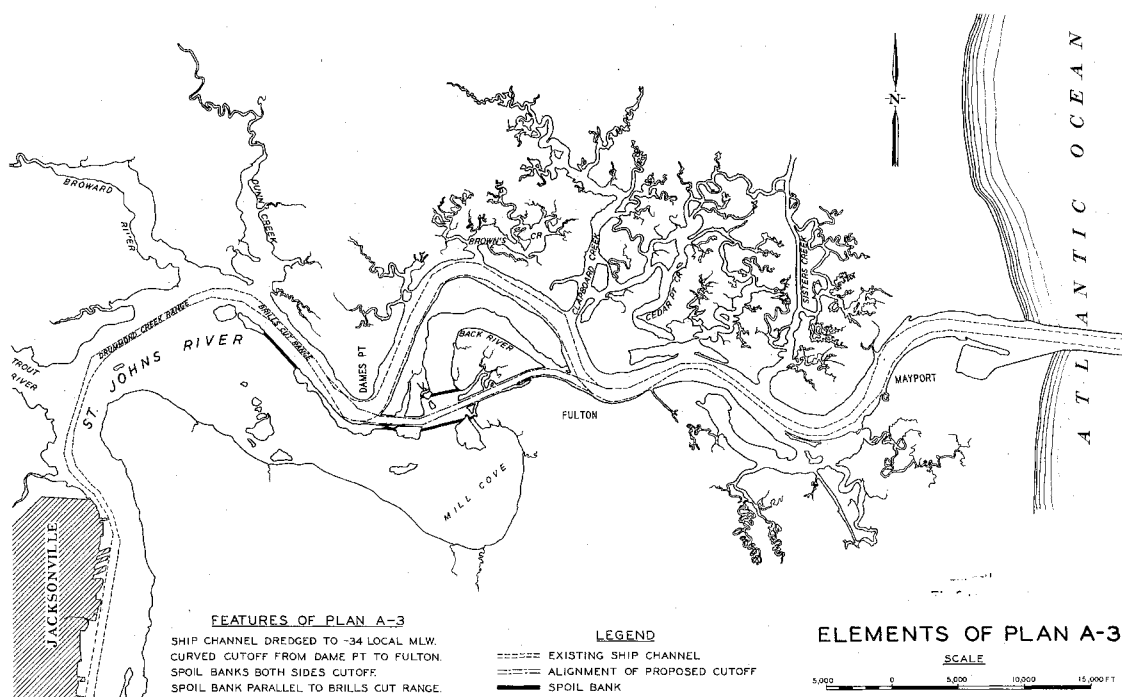


Fig. 8

gaps between existing spoil banks parallel to Brills Cut Range. It was the purpose of this test to ascertain whether the stopping of these gaps to eliminate the cross currents from the Mill Cove area after high-water slack would have the effect of creating an objectionable cross flow out of the Mill Cove area into the river at Drummond Creek range.

### Results

45. Since the significant features of this test were the flow patterns into and out of Mill Cove at Drummond Creek Range, and the tidal heights in Mill Cove, only data pertinent to those features are presented. Tidal heights for Plan A-3 are presented on plates 50 and 51; flow patterns are shown on photograph 20. The significant results of the test were: (a) the tidal range in the Mill Cove area was reduced by about 0.2 ft from its Plan A-1 proportions; and (b) the flow from the Mill Cove area into the river at Drummond Creek Range did not create an objectionable cross flow at that point. The maximum salinity profile with this plan in operation was the same as for plan A-1 (see plate 30).

### Plan B-1

#### Description

46. The elements of Plan B-1 may be seen on figure 9. The plan comprised a straight cutoff from Dames Point to Fulton. This cutoff departed from the river opposite Dames Point, passed through Back River at a point slightly farther south than did the Plan A alignment, and rejoined the St. Johns River slightly west of St. Johns Bluff, passing directly through the town of Fulton and traversing an adjacent terrain

as high as 30 ft above mean sea level. The plan incorporated dikes on both sides of the cutoff at its intersection with Back River. The cutoff was 34 ft deep at local mean low water and had a bottom width of 500 ft.

### Results

47. Plan B-1 tidal heights are shown on plates 52 and 53, current velocities on plates 54-60, flow patterns on photographs 21-24, and salinity on plate 30. The effects of Plan B-1 upon the river were not substantially different from those of Plan A-1, the changes from the base test in the case of each plan being of approximately the same magnitude. The most significant aspect of the Plan B-1 condition was the failure of the flood currents to make a satisfactory entrance at the Fulton end of the cutoff. The determining factor appeared to be the

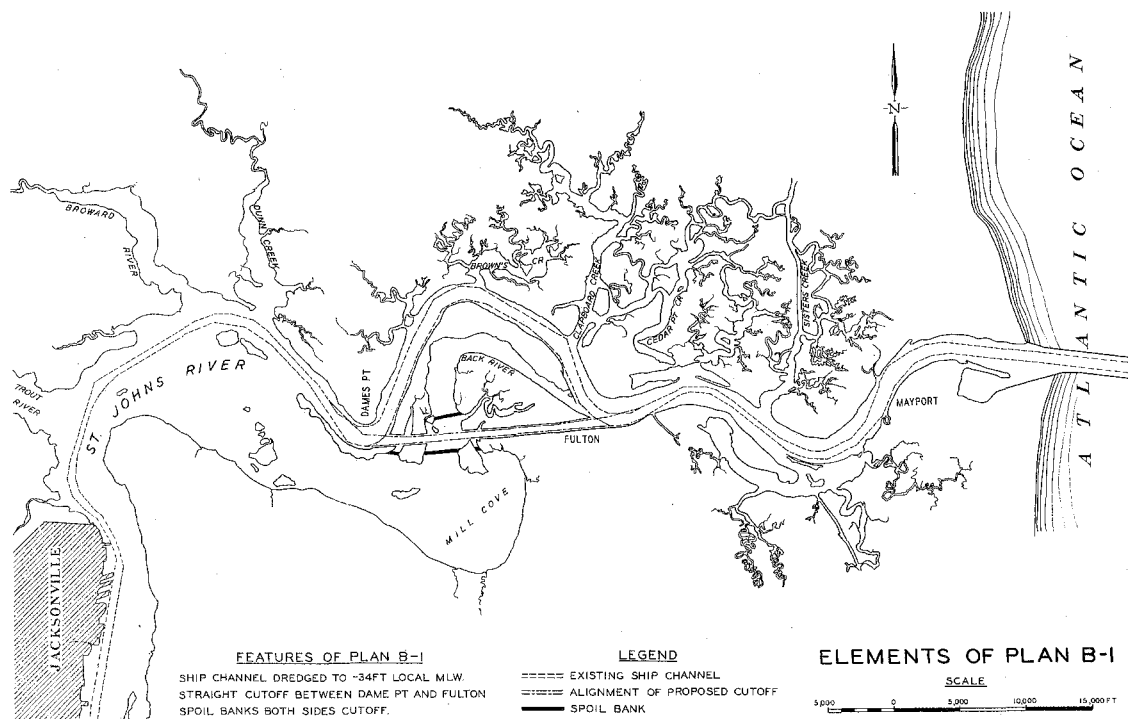


Fig. 9

tendency of flood currents to follow the north bank of the river opposite St. Johns Bluff. This tendency was also exhibited in the base test and appeared to be due to a condition downstream from the cutoff which was unchanged by any of the improvements. It is not believed that navigation would be adversely affected by this condition; however, there is a possibility that shoaling might result in the downstream entrance to the cutoff. The profile of maximum salinity for Plan B-1 was substantially the same as for Plan A-1 (see plate 30).

### Plan B-5

#### Description

48. Plan B-5 (figure 10) reproduced Plan B-1 conditions with the addition of a wider flare at the downstream end of the cutoff. It was

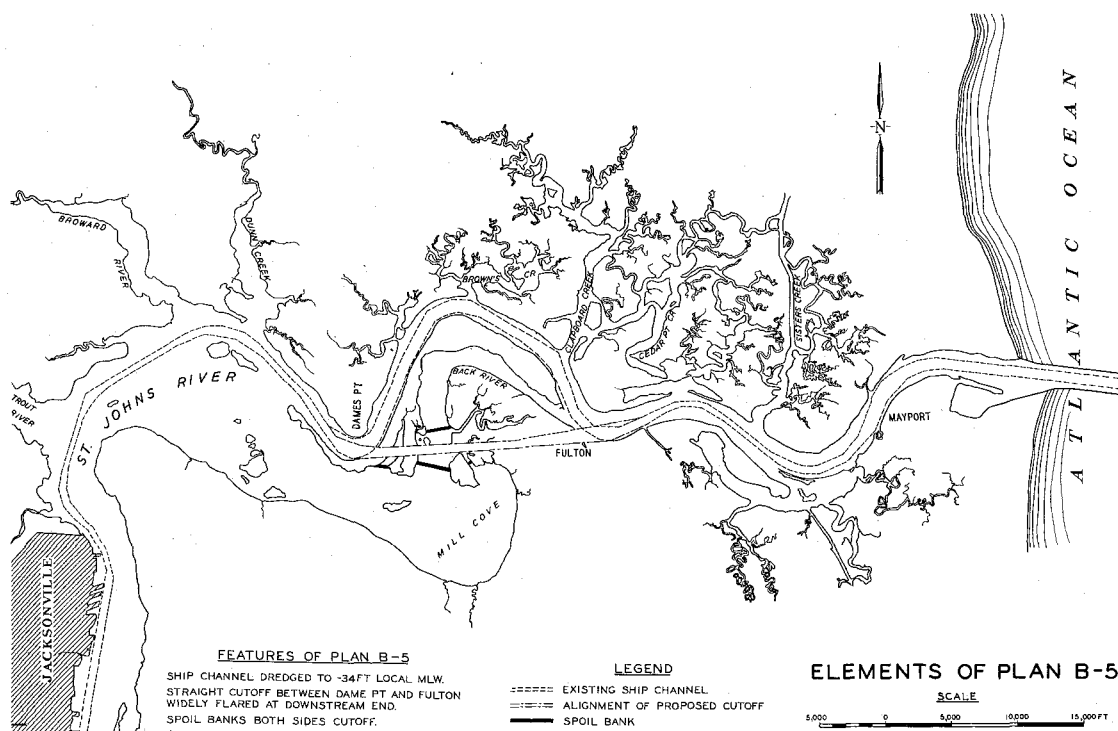


Fig. 10

the purpose of this plan to ascertain whether the addition of this flare would improve the entrance conditions observed at the lower end of the Plan B-1 cutoff, and to provide a wider entrance for ships, should warping be necessary in the navigation of the converging currents of the cutoff and the intercepted reach of the river.

### Results

49. Since the effects of Plan B-5 upon tidal heights, current velocities, and salinity were substantially the same as those of Plan B-1, data pertaining to these phenomena are omitted. The most important result of the plan was its effect upon the entrance conditions at the downstream end of the cutoff. Flow patterns in this area may be seen on photographs 25-28. It appears from a comparison of these photographs with those for Plan B-1 that the downstream entrance conditions for flood tide were somewhat improved by the addition of the flare. The maximum salinity profile for Plan B-5 was, for all practical purposes, the same as is shown for Plan B-1 on plate 30.

### Plan C-1

#### Description

50. The elements of Plan C-1 are shown on figure 11. The most significant feature of this plan was the modified straight cutoff from Dames Point to Fulton. This cutoff departed from the St. Johns River opposite Dames Point, crossed Back River in approximately the same place as did the Plan A alignment, and rejoined the river at the mouth of Back River (Shipyard Reach) opposite Fulton. This cutoff did not pass through

Fulton or traverse the adjacent high terrain. The cutoff was diked on both sides where it intersected Back River. It was 34 ft deep at local mean low water and had a bottom width of 500 ft except in its entrance flares. The alignment of this cutoff offered the advantage to navigation of providing a single range.

### Results

51. Since the river above Jacksonville was not significantly affected by the installation of this plan, no data pertaining to that reach of the river are presented. Tidal heights for Plan C-1 are shown on plates 61 and 62, current velocities on plates 63-69, flow patterns on photographs 29-32, and salinity on plate 30. These tidal heights and current velocities were not significantly different from those of Plans A-1 and B-1. It appears from the flow-pattern photographs that the Plan

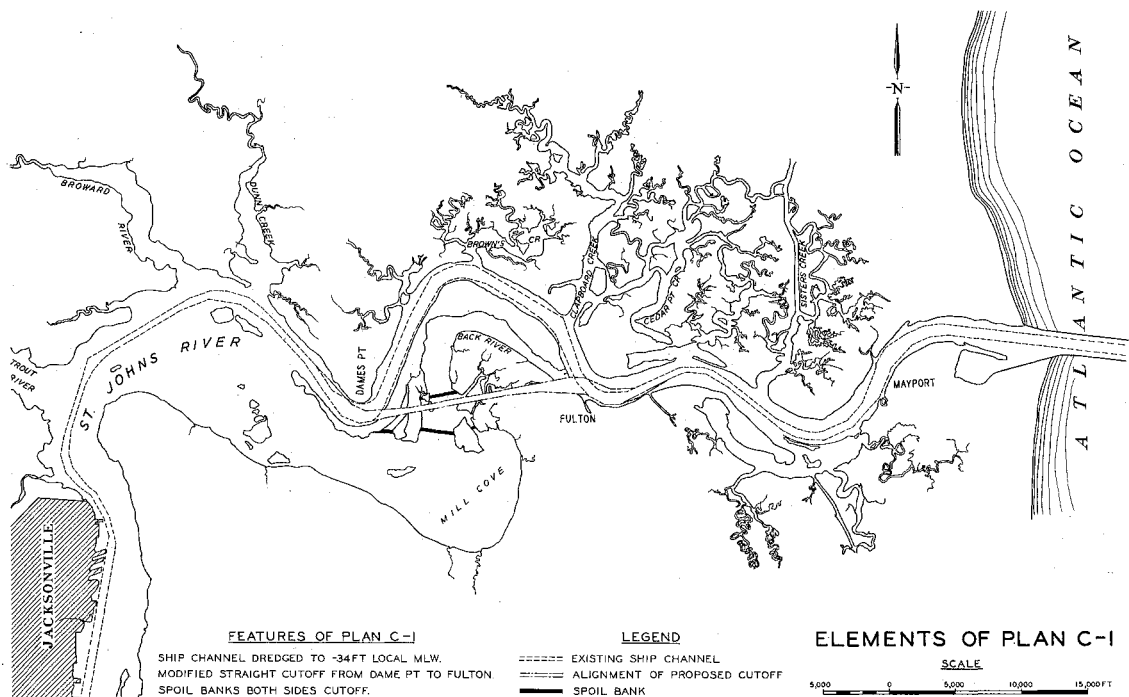


Fig. 11



C-1 condition did not offer so good an entrance at the downstream end of the cutoff as did the Plan B-5 condition. Plan C-1 effected a slightly greater increase in maximum salinity upstream from the cutoff than did either Plan A-1 or Plan B-1 (see plate 30).

### Plan C-6

#### Description

52. The elements of Plan C-6 are shown on figure 12, and were identical with those of Plan C-1, except that a 100-ft opening with a bottom depth of 10 ft at local mean low water was provided in the dike across Back River south of the cutoff. It was the purpose of this test to ascertain whether the opening in the dike, which was incorporated in the plan to allow for tidal circulation in Mill Cove and for navigation

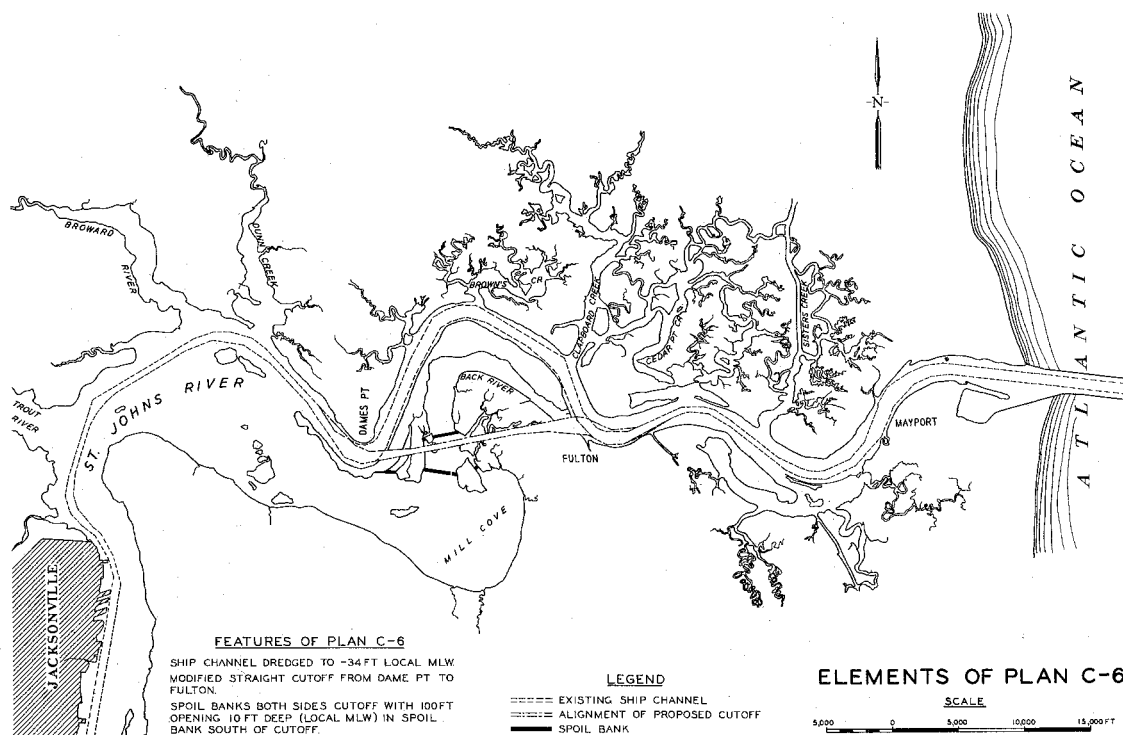


Fig. 12

therein by small craft, would cause sufficiently high velocities from Mill Cove into the cutoff channel to be hazardous to navigation.

### Results

53. Since the effects of the opening in the south dike were entirely local, only data pertaining to the immediate area of the cutoff are presented. Tidal heights are shown on plate 70, current velocities on plates 71-73, and flow patterns on photographs 33-35. The most significant result noted during this test was the high current velocities through the opening in the dike (photograph 33). As may be seen from surface current velocity observations at station 16, the maximum ebb velocity through the gap was 7.5 ft per sec and the maximum flood velocity was 6.0 ft per sec. While these high velocities would make navigation of the gap dangerous during all but a few hours of the day, it is apparent from the photographs that the cutoff was relatively unaffected thereby. It appears from the tidal curve for Gilmore that the tidal range was restored to approximately its base-test proportions. The maximum salinity profile for Plan C-6 was the same as is shown on plate 30 for Plan C-1.

### Plan C-7

#### Description

54. The elements of Plan C-7 are shown on figure 13. This plan reproduced all the features of Plan C-6 with the addition of parallel 100-ft training walls extending into Mill Cove perpendicular to the dike across Back River. This test was performed to determine whether the

addition of these dikes would reduce appreciably the high current velocity through the opening in the dike as noted during the test of Plan C-6.

### Results

55. Since the effects of this plan were entirely local, only data pertaining to the immediate cutoff area are presented. Tidal heights are shown on plate 74, current velocities on plates 75-77, and flow patterns on photographs 36 and 37. It appears from a comparison of the velocities through the opening in the dike with those of Plan C-6 that the addition of the parallel training walls decreased the maximum ebb velocity by 1 ft. per sec and the maximum flood velocity by 2 ft per sec. Navigation of the opening by small craft would be limited under this plan, however, to a few hours a day, as in the case of Plan C-6. No

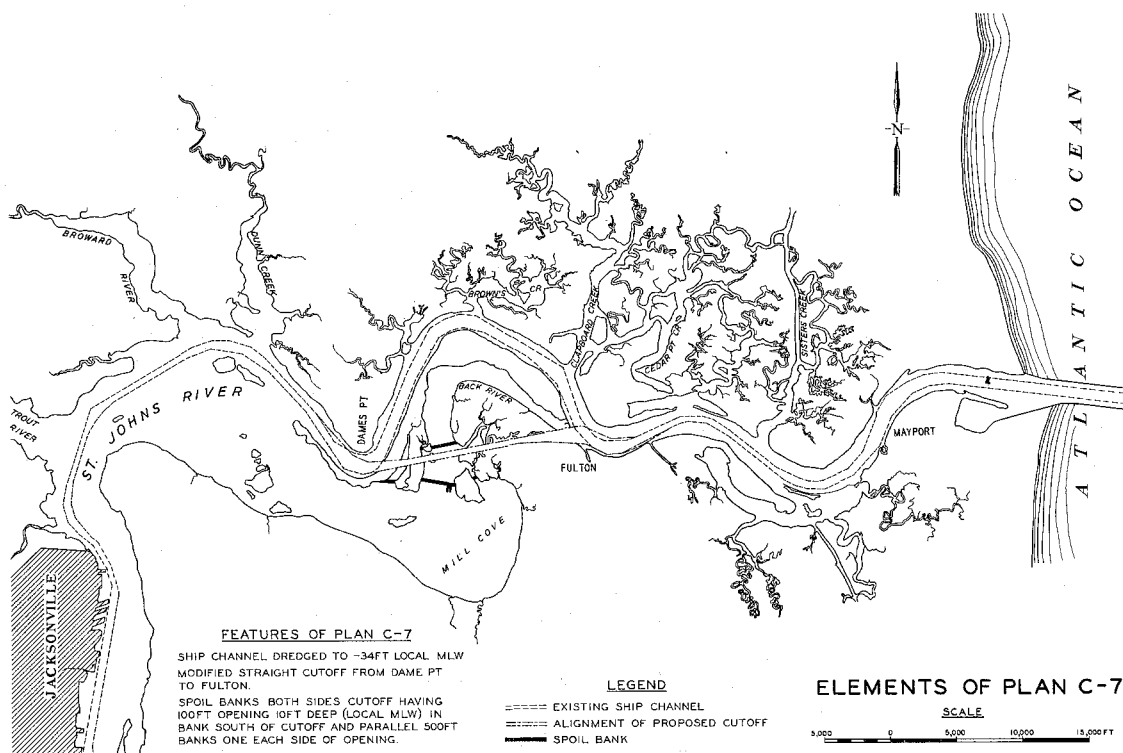


Fig. 13

hazardous cross currents in the cutoff were observed to result from Plan C-7. The maximum salinity profile for Plan C-7 was the same as is shown on plate 30 for Plan C-1.

### Plan D-1

#### Description

56. The elements of Plan D-1 are shown on figure 14. The significant feature of this plan was the shifting of Wards Bank training wall into a position parallel with Bar Cut Range and the elongation of the training wall to 5000 ft (extending from mile 1.23 to mile 2.28). The purpose of this test was to ascertain whether realignment and extension of the training wall would increase current velocities in the river adjacent to the training wall and between the jetties, and thus reduce the

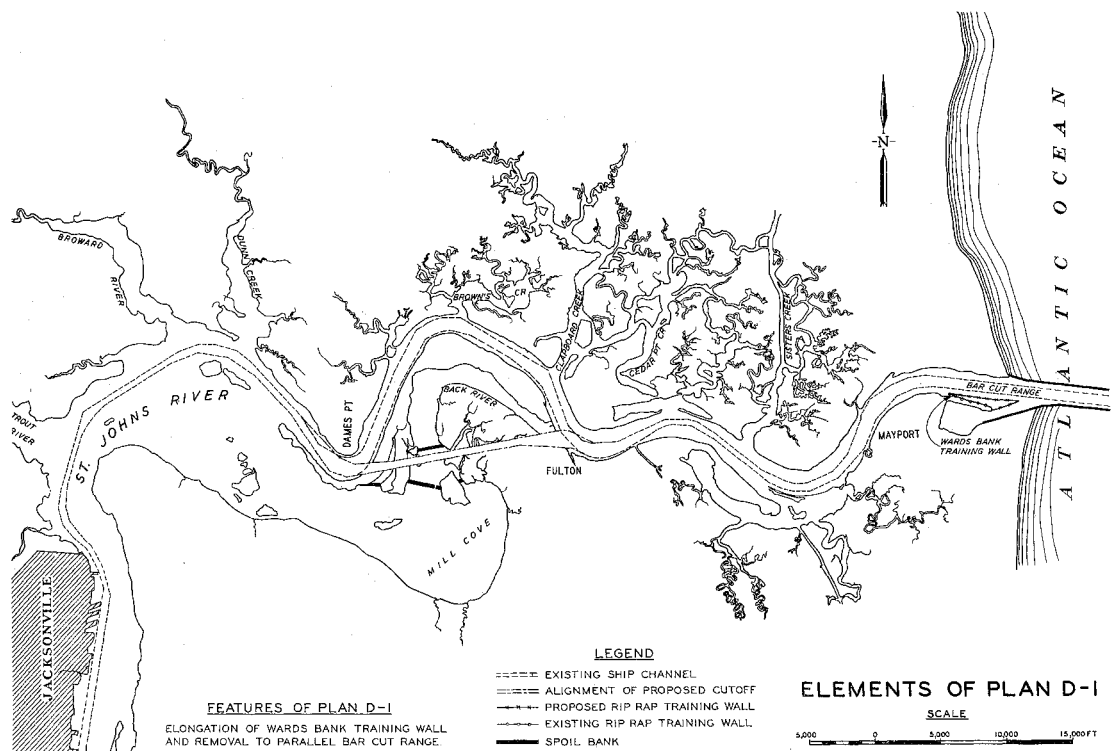


Fig. 14

amount of shoaling at present occurring in that range of the river. For the purpose of measuring current velocities in this vicinity, three new stations (17, 17A, and 17B) were added along the north jetty (figure 4). Tests of this plan were made with Plan C-6 conditions installed in the model.

### Results

57. Current velocities for Plan D-1 are shown on plates 78-80. Flow patterns during the testing of Plan C-6, before Plan D-1 was installed, are shown on photographs 38-40 for comparison with flow patterns obtained during the test of Plan D-1, as shown on photographs 41-43. Since the effects of the plan were local, only local data are presented. The comparative current velocity curves for Plans C-6 and D-1 indicate that the installation of Plan D-1 in the model had the effect of increasing the ebb velocities by a considerable amount at all stations and depths in the problem area. No salinity data were obtained for Plan D-1, since it was felt that this plan would not change existing salinity conditions throughout the river.

## PART V: DISCUSSION OF RESULTS

### Model Accuracy

58. The attainment of the proper adjustment of the St. Johns River model and the development of the model operating technique (which, when developed, was followed on all tests) were the results of several months' effort and study by personnel of the Experiment Station. The reliability of the results of the study rests upon the verification procedure. The results of the verification test demonstrated the ability of the model to reproduce accurately the tidal heights, current velocities, and salinities observed in the prototype.

### Effects of the Cutoff Plans

59. The most salient feature of the results of the plans tested, and one which is readily apparent from a study of this report, was the fact that none of the plans tested caused any significant change in the river or the tidal regimen therein. The effects of all the cutoff alignments were confined for the most part to the area in which the improvements were made, the tidal range and current velocities at Jacksonville and above remaining relatively undisturbed. Each of the cutoff plans caused a slight decrease in maximum salinity at the downstream end of the cutoff, and a slight increase in maximum salinity from the upstream end to the vicinity of Dredge Depot. However, these slight changes are not considered to be significant.

Comparative merits of the three cutoff alignments

60. Curved cutoff. The curved cutoff exhibited satisfactory hydraulic characteristics. When dikes were placed across Back River on each side of the cut, the currents through the cut appeared to be of sufficient velocity to keep the channel open, but not so high as to cause serious erosion of the banks. It is probable that as the intercepted reach of the river shoaled, the cutoff would gradually widen itself. The entrance conditions at the lower end of the cutoff were excellent, while conditions at the upper end were slightly better with the narrow flare than with the wide one. The cutoff had the disadvantage of consisting of several ranges, and at night or in heavy fogs, the meeting and passing of vessels within its narrow confines would probably be hazardous.

61. Straight cutoff. The hydraulic characteristics of the straight cutoff were also satisfactory. Entrance conditions at the downstream end were more satisfactory for the wide flare than for the narrow one. Entrance conditions at the upstream end were satisfactory. The flow through the cutoff, when dikes protected it from cross currents out of Mill Cove and Back River, was probably of sufficient velocity to keep the channel open, and perhaps to widen it gradually as shoaling reduced the cross section of the intercepted reach of the river. This alignment had the advantage of consisting of a single range, which would considerably facilitate navigation therein. The straight cutoff had the economic disadvantage of passing directly through the site of the town of Fulton and of traversing the higher terrain adjacent to it.

62. Modified straight cutoff. The hydraulic characteristics of

the modified straight cutoff were satisfactory. Entrance conditions at the downstream end were not quite so good as those of the straight cutoff with the wide flare. Upstream entrance conditions were satisfactory. The alignment of this cutoff had the advantages of consisting of a single range, of avoiding Fulton and the higher terrain adjacent to it, and of providing a wide downstream entrance.

#### Effects of Improvement Plans upon Conditions in Mill Cove

63. It became apparent during the testing of Plan A that the intersection of a cutoff of any alignment whatever with Back River where it joins Mill Cove would create a navigation problem, since the flow out of the considerable Mill Cove area swept out into the cutoff channel, generating hazardous cross currents. All cutoff alignments subsequently tested incorporated dikes across Back River on each side of the cutoff to rectify this situation. Such a condition, however, resulted in objectionable cross currents, though of less magnitude and duration, into Brills Cut. It was found that the flow from the Mill Cove area into the river at Drummond Creek Range, caused by the placing of dikes along Brills Cut, was not objectionable, but that as a result of the placing of dikes at the cutoff and at Brills Cut, Mill Cove became a stagnant body of water without tidal circulation and without a satisfactory opening for navigation. In order to alleviate this situation an opening was made in the dike south of the cutoff. Tidal circulation was restored to Mill Cove by this means, but current velocities through the opening rendered it hazardous for navigation except for the hours near slack water. Although the addition of parallel dikes perpendicular to the



dike across Back River reduced the velocities in the opening, they did not render it navigable for an appreciably greater portion of the tidal cycle.

#### Wards Bank Training Wall Improvements

64. It is believed that the shoaling situation in Bar Cut Range adjacent to the north jetty would be considerably alleviated by the installation of the Plan D-1 features in the river. The source of the shoal material is not known. If the material is brought down from the reaches upstream, and if shoaling occurs along the jetty because of low velocities in that vicinity, the relocated training wall would function in two ways to improve the situation: (a) it would prevent future deposition by increasing the velocity, and (b) it would probably scour such shoaling as might be present. If the material is deposited by the action of the sea through the rubblestone jetty, the higher velocities created by the relocated training wall would probably tend to carry away the material brought in by the sea before it could be deposited and scour out any shoaled material that might be present.

## PART VI: SUMMARY OF CONCLUSIONS

65. It may be said that any of the three cutoff alignments would perform satisfactorily. From the standpoint of navigation, the straight cutoff with a wide flare at its lower entrance (Plan B-5) would be better than either of the other two. However, its construction would offer greater difficulties due to the high terrain which it traverses than would that of either of the other two; its cost would be greater; and the procurement of a right-of-way therefor would be more difficult since it passes directly through an inhabited area. If these undesirable features should outweigh its merits, excluding it from consideration, a comparison of the curved cutoff (Plan A-1) with the modified straight cutoff (Plan C-1) indicates that the latter would be the more desirable, since the curved alignment would be more difficult to navigate, especially at night and during foggy weather.

66. It appears from the results of the tests that whatever the alignment of the cutoff, it must be diked at its intersection with Back River. The placing of solid dikes across Back River at this point would also necessitate closure of the openings in the spoil banks at Brills Cut to prevent objectionable cross currents into the navigation channel at that point. An opening in the dike south of the cutoff would provide tidal circulation into and out of Mill Cove, and thus prevent Mill Cove becoming stagnant; however, the opening in the dike would be navigable for only a short portion of the day. It is believed that no satisfactory plan was tested that would provide for both tidal circulation in Mill Cove and for free navigation therein. The addition of training walls at

the opening decreased somewhat the high velocities, but not sufficiently to make the opening safe for navigation by small craft except for the hours near slack water.

67. Although no quantitative data could be obtained from the model which would show the effects on shoaling of relocating and extending Wards Bank training wall, a study of the effects of this plan on current velocities in the affected reach of the river indicates that shoaling in Bar Cut Range would be reduced appreciably by construction of the plan.

68. The extensive tidal tributaries between Jacksonville and the Atlantic Ocean, the large Mill Cove area, and the wide lagoon between Jacksonville and Palatka offer such a storage capacity as to damp the effects of the improvement plans upon the river as a whole. The current velocities from the cutoff to Jacksonville were increased slightly by the installation of the cutoff plans. This did not result in an increase in tidal range at Jacksonville or above. The general statement may therefore be made that the effects of the improvement plans tested upon the regimen of the river and upon the harbor as a whole were negligible.

## PHOTOGRAPHS





PHOTOGRAPH 2



Base Test  
Hour 9  
Flood



Base Test  
Hour 8  
Flood



Base Test  
Hour 7  
Flood







PHOTOGRAPH 6





Plan A  
Hour 9  
Flood



Plan A  
Hour 8  
Flood

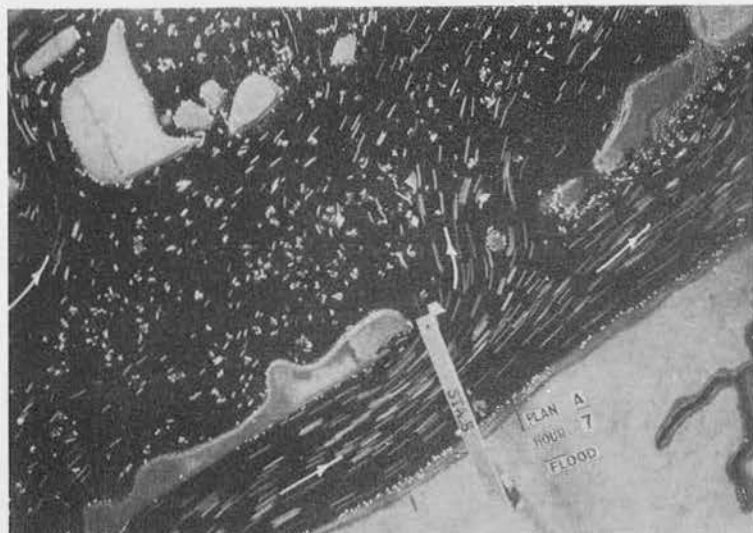
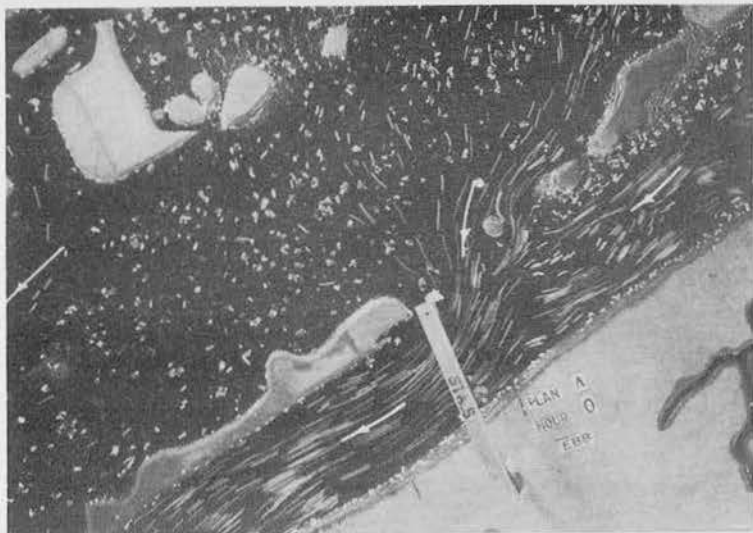
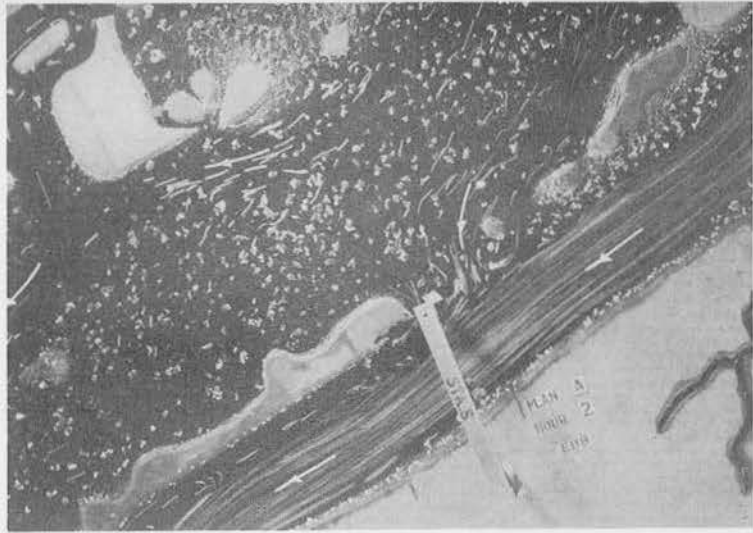


Plan A  
Hour 7  
Flood

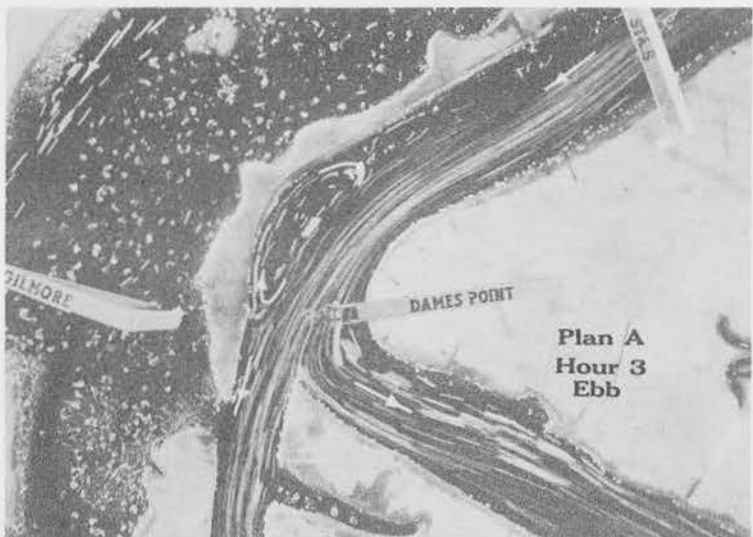
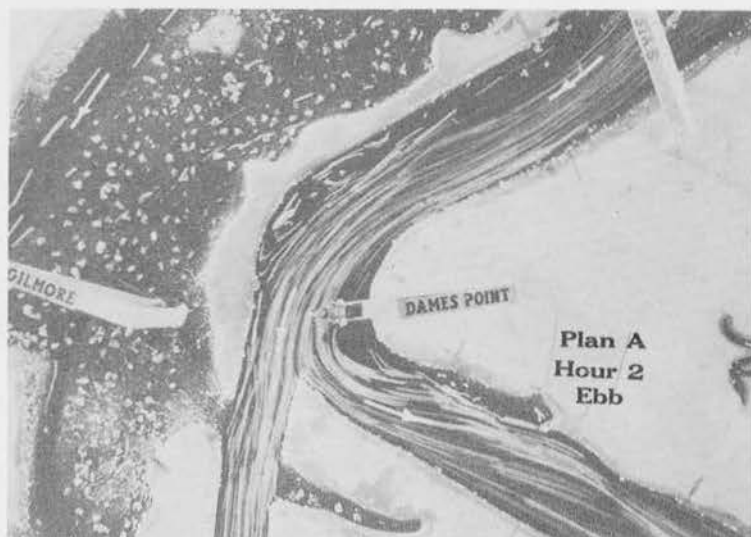
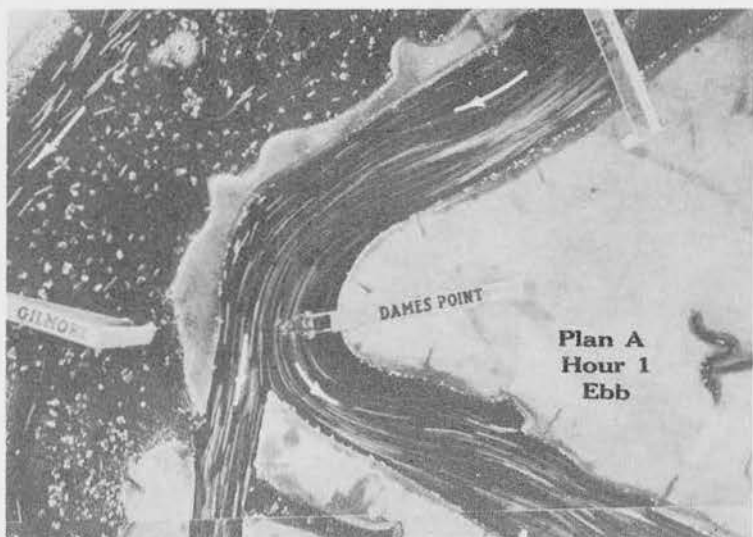
PHOTOGRAPH 8

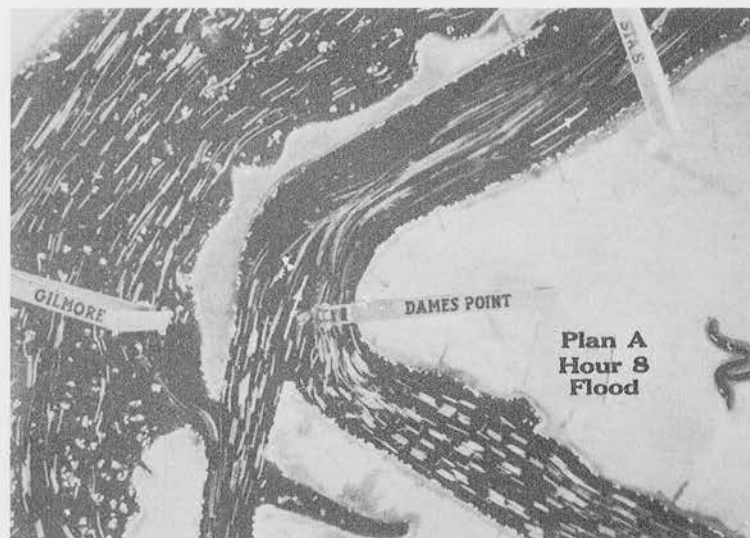
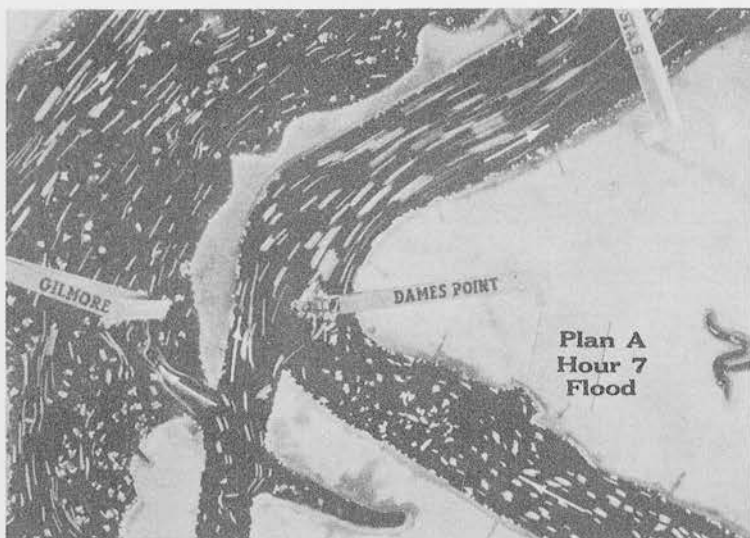
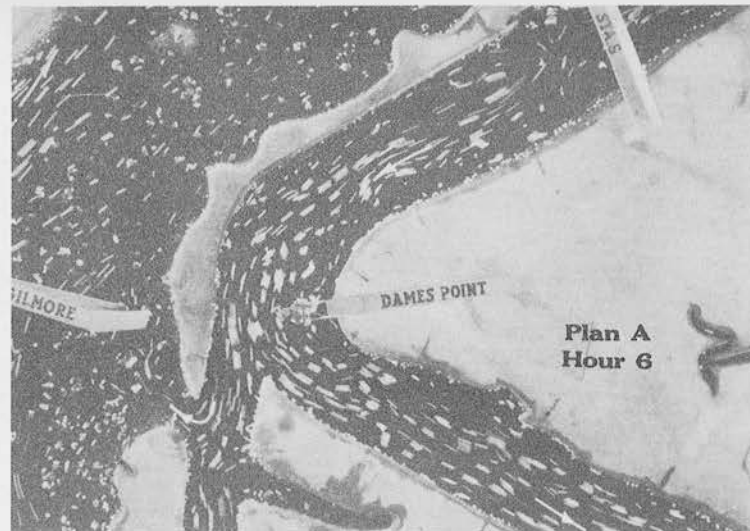
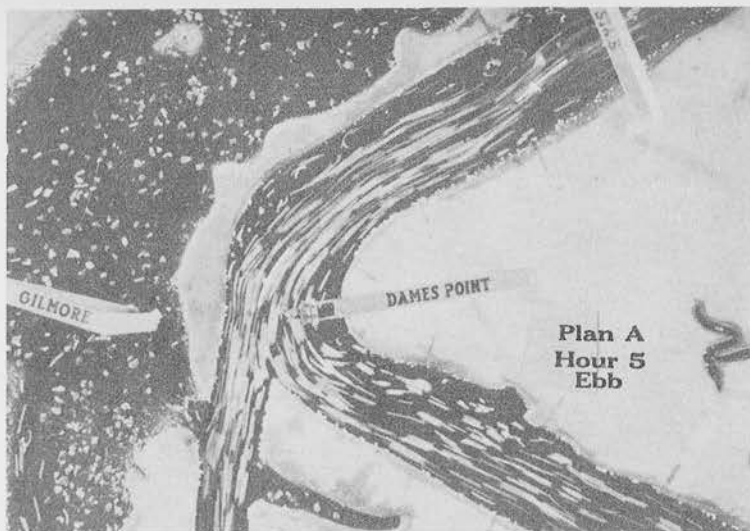


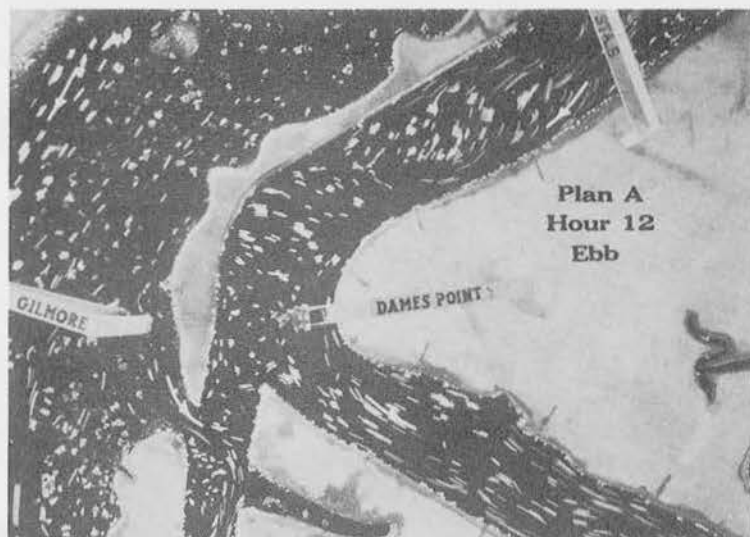
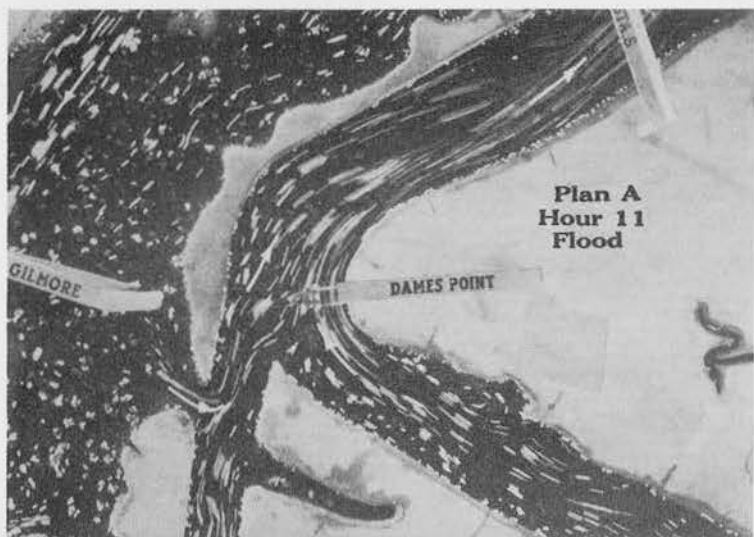
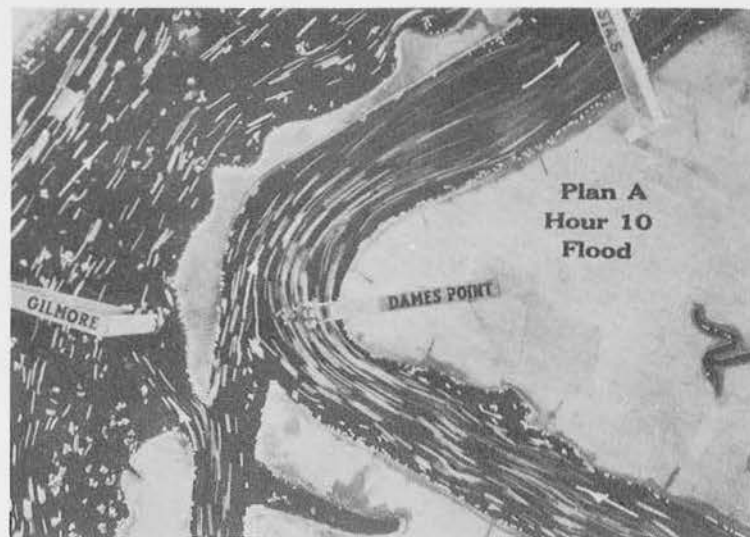
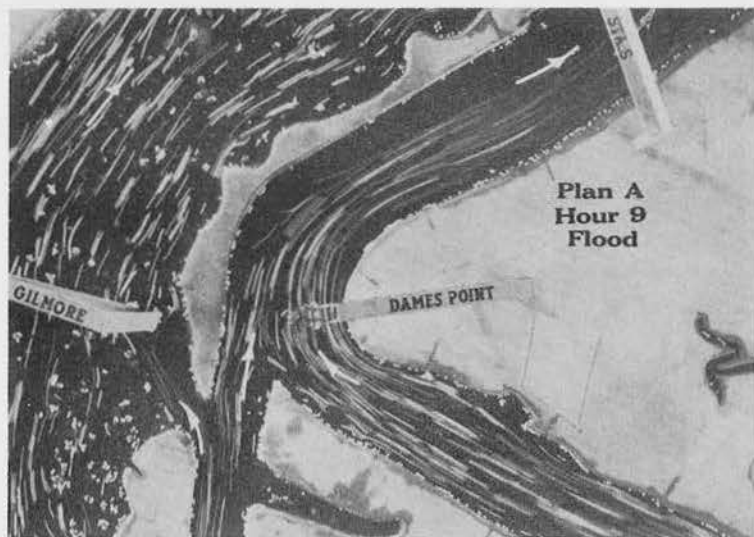




PHOTOGRAPH 9



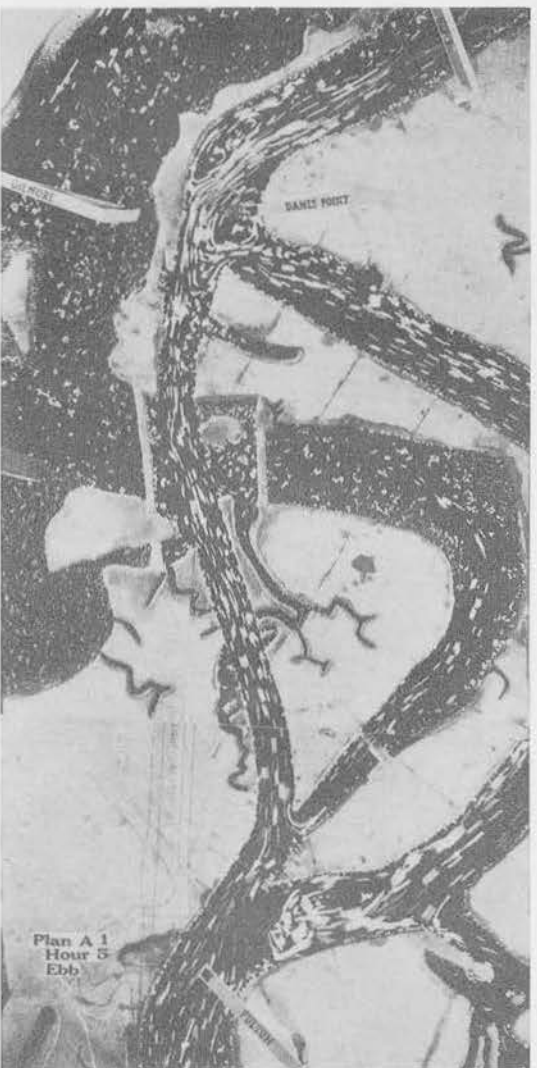






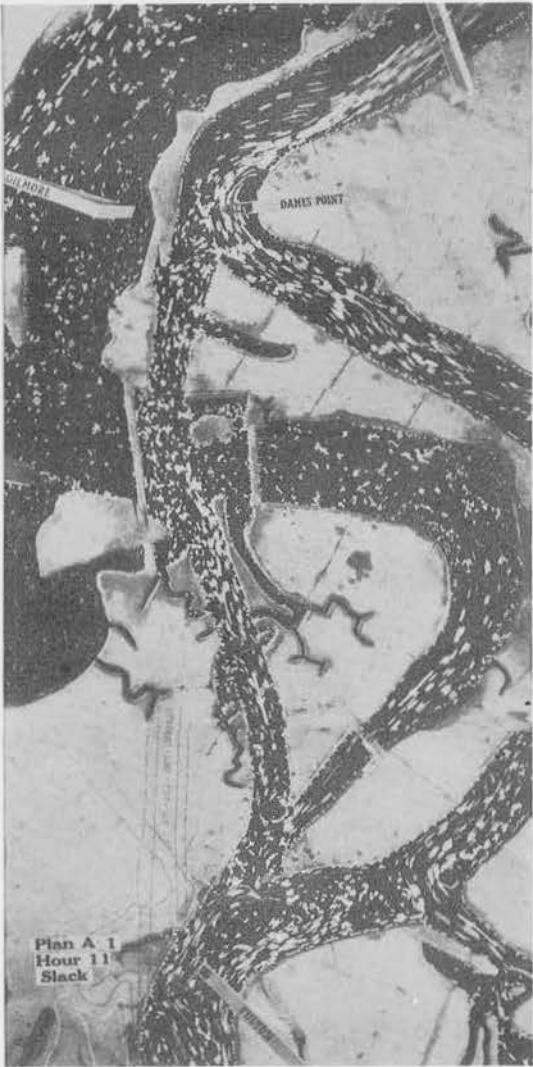
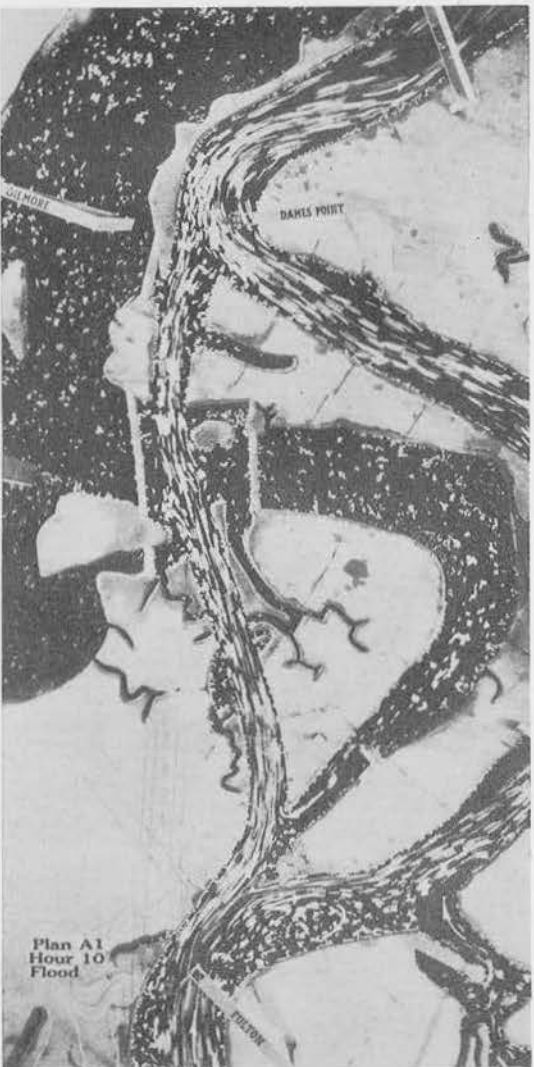


PHOTOGRAPH 13

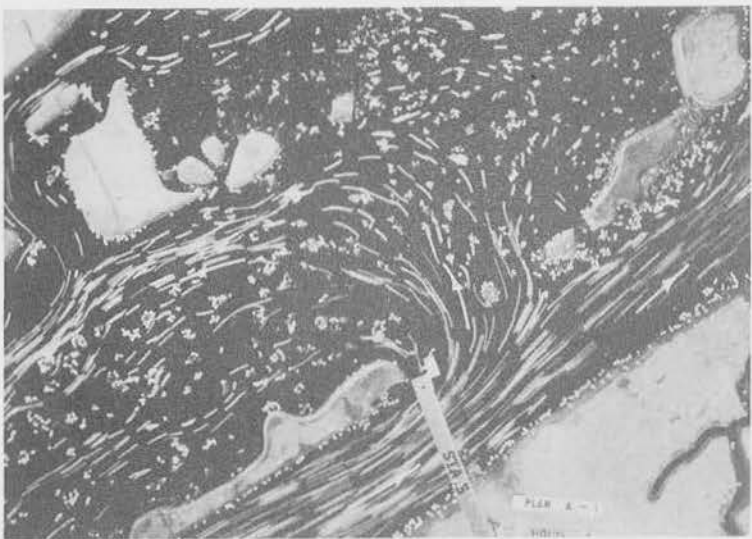
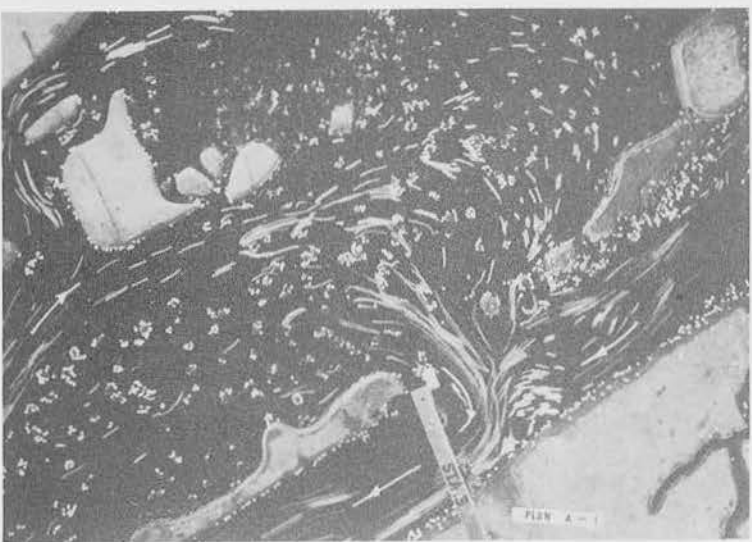
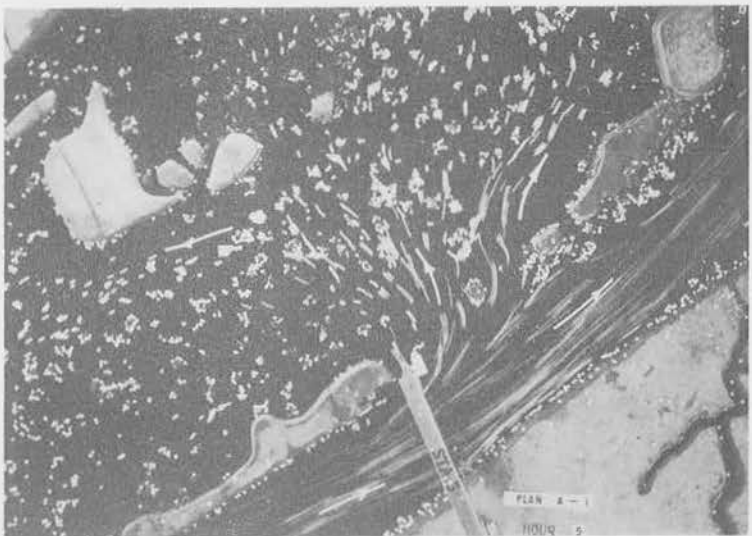
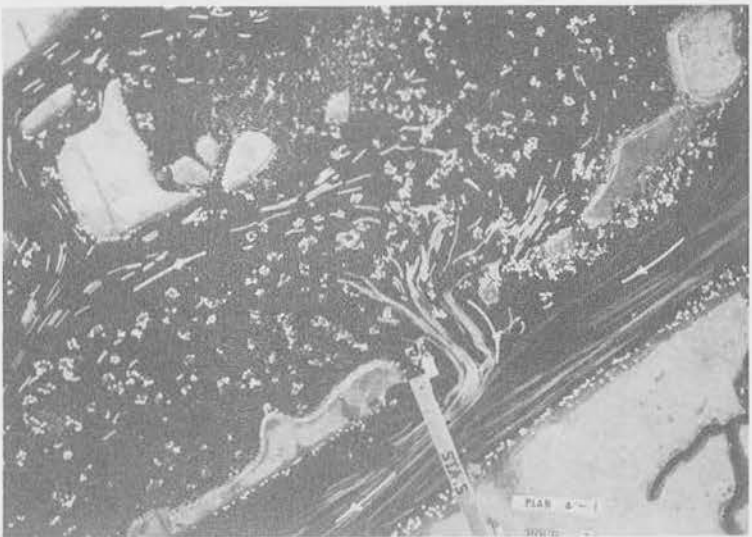


PHOTOGRAPH 14





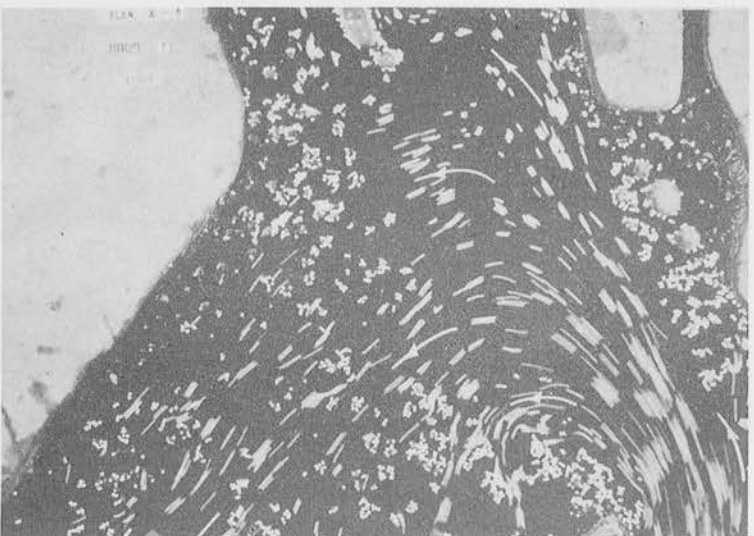
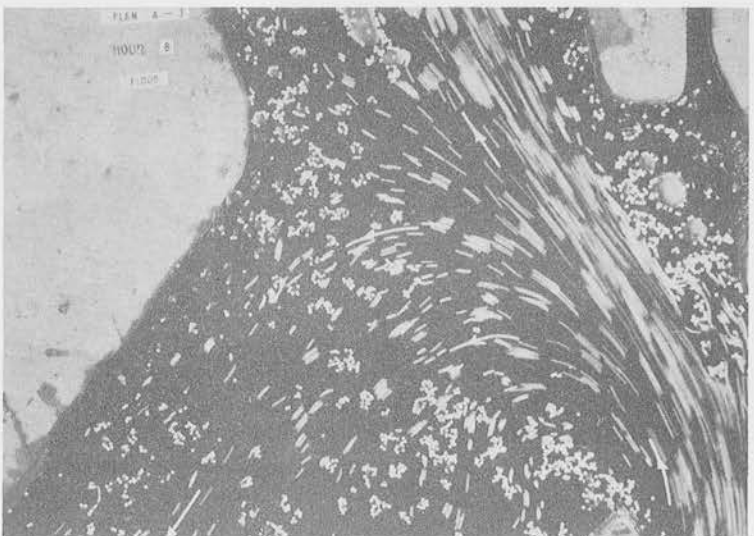
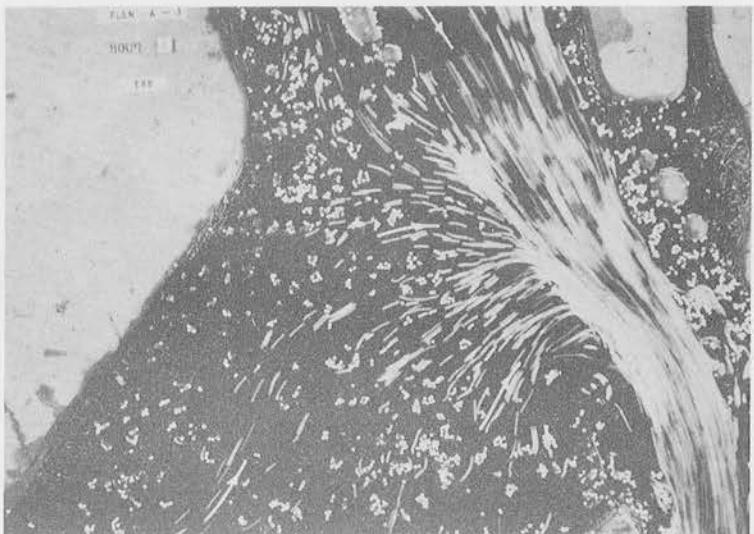




PHOTOGRAPH 17

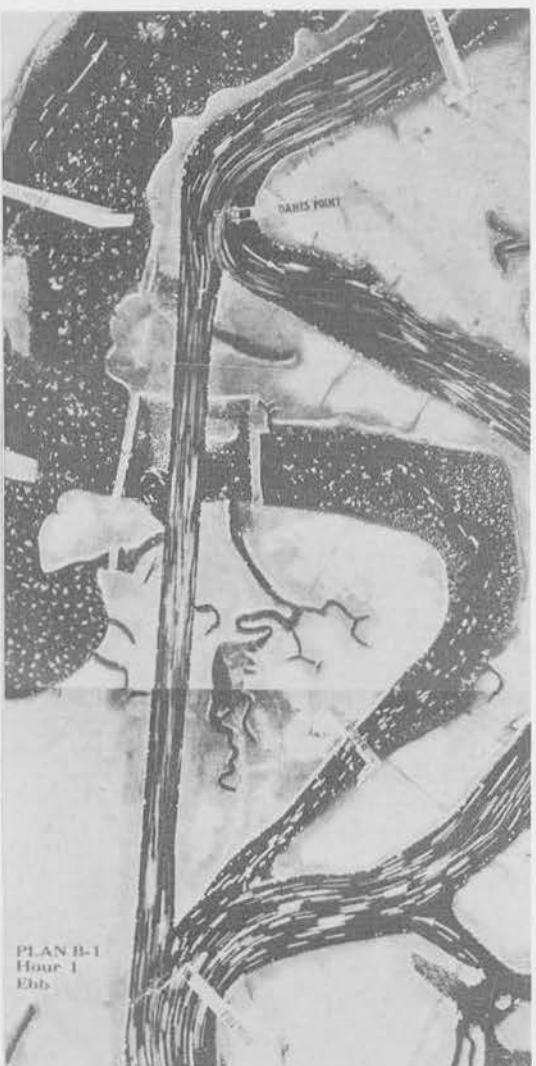
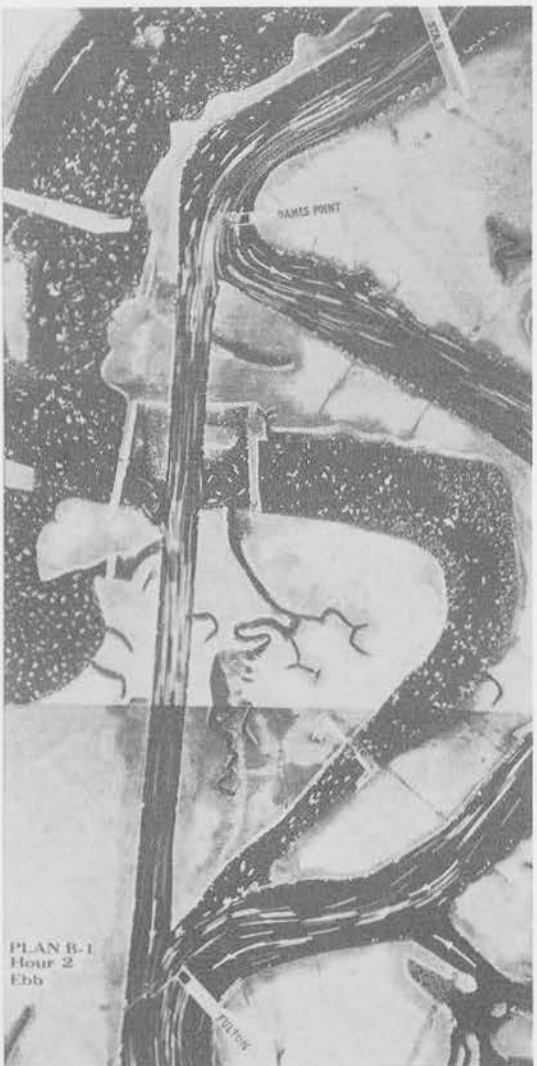


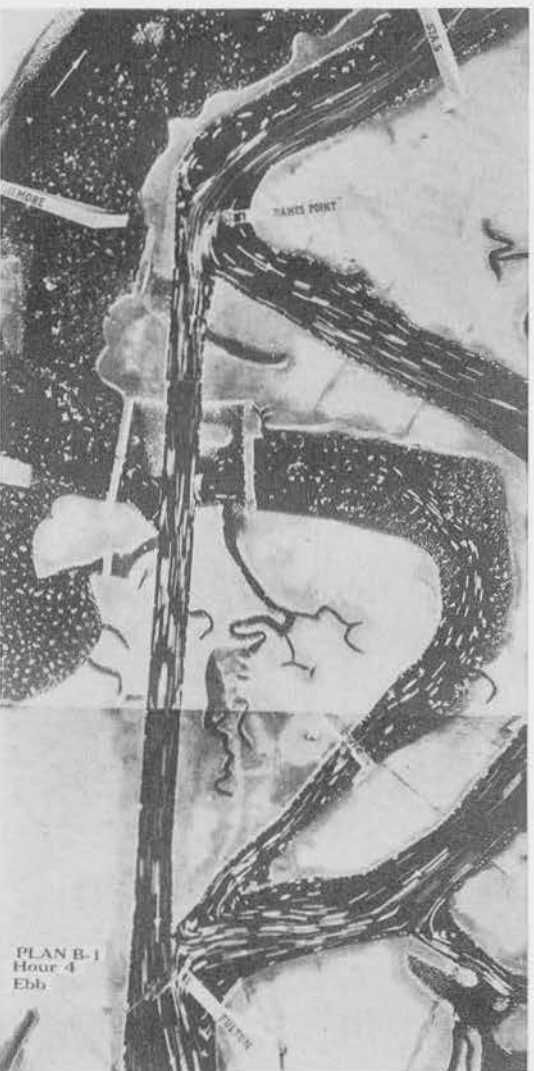
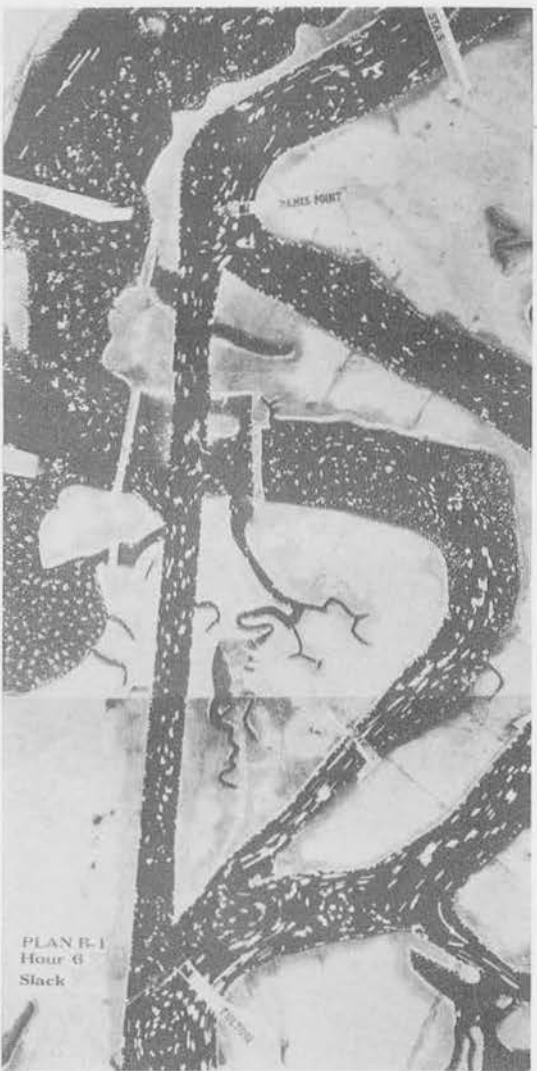




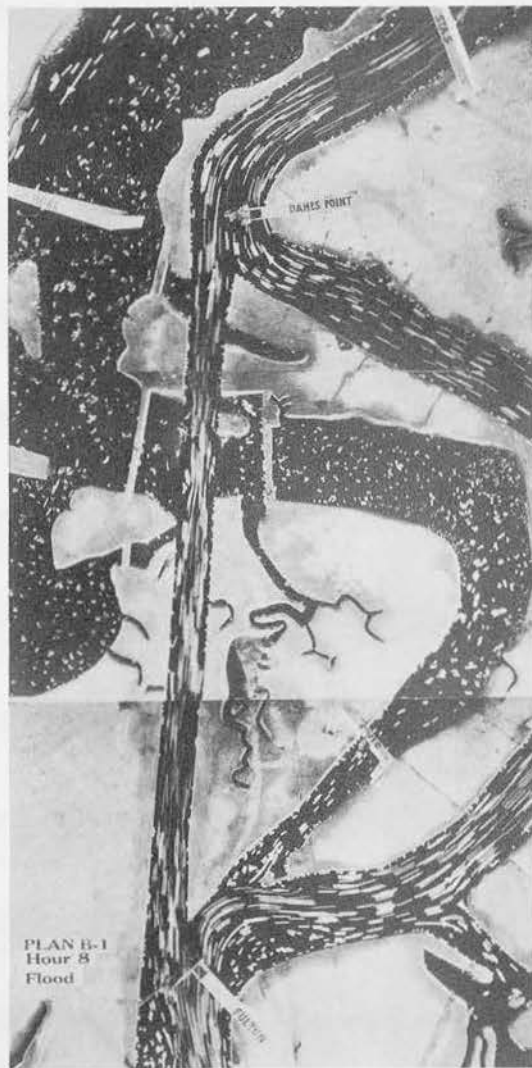
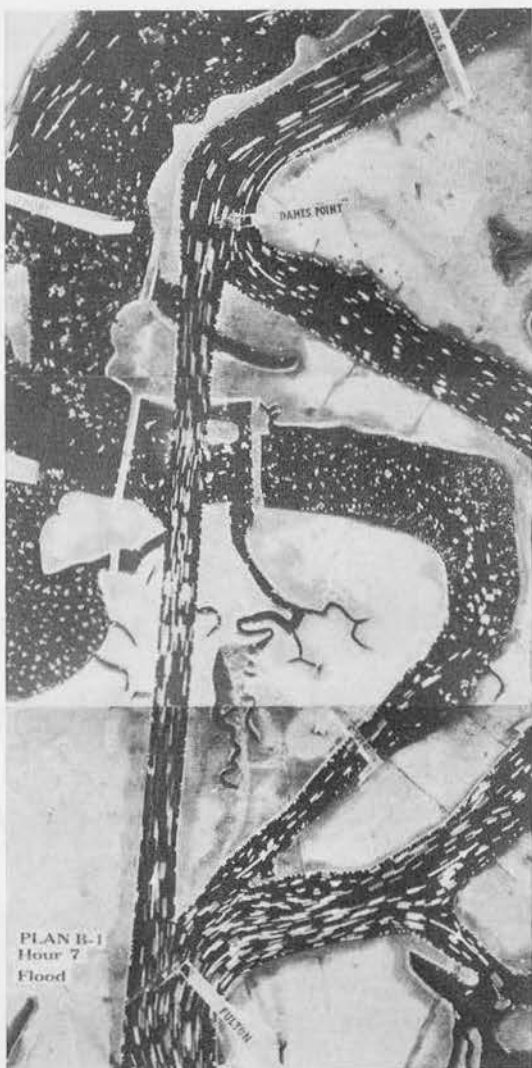
PHOTOGRAPH 20

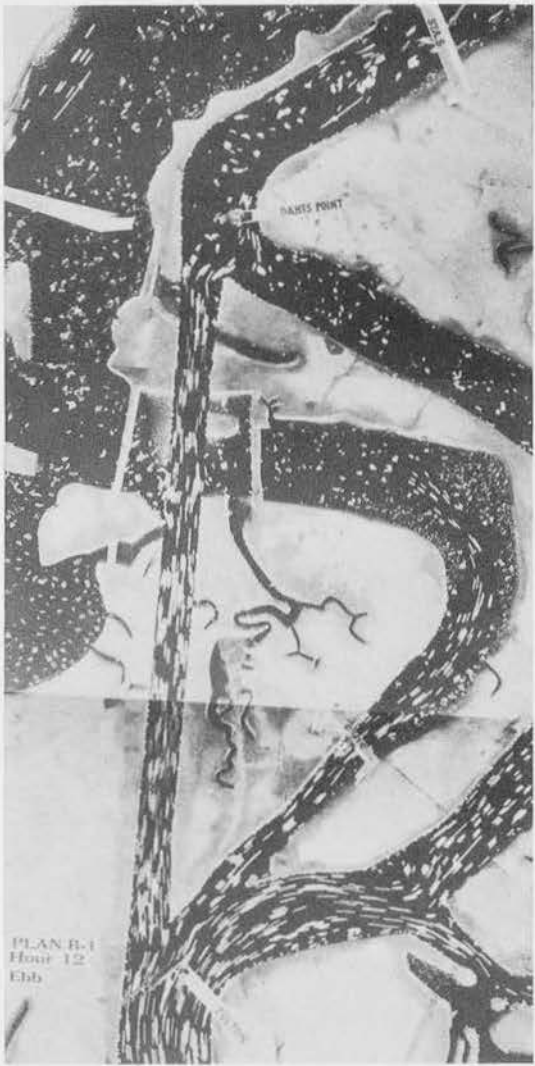
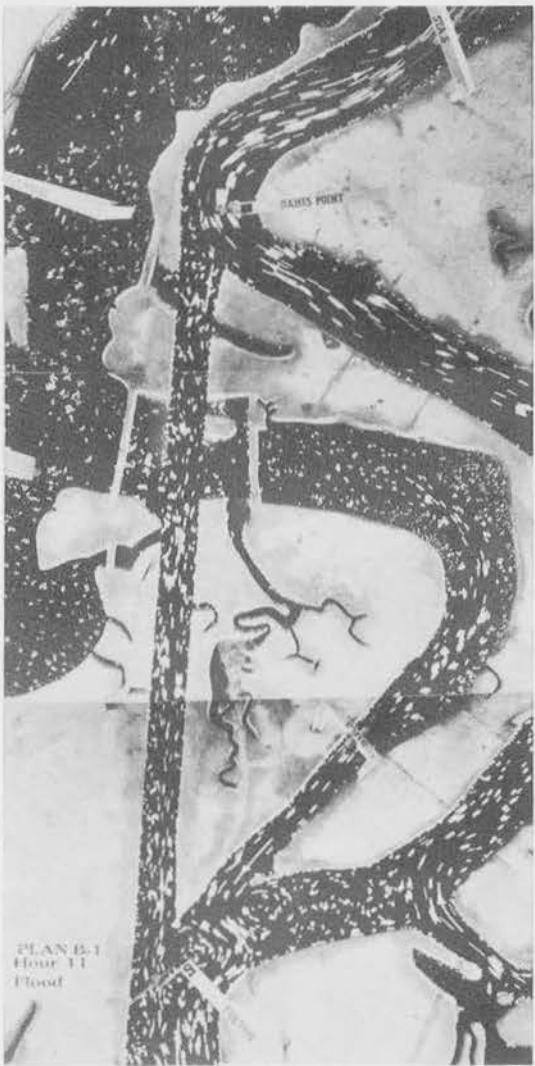
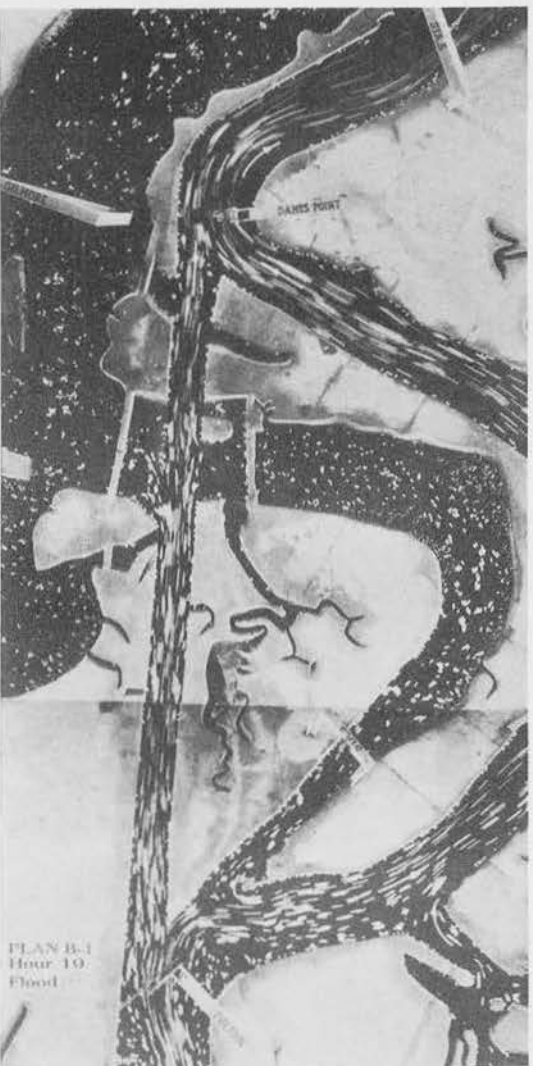






PHOTOGRAPH 22





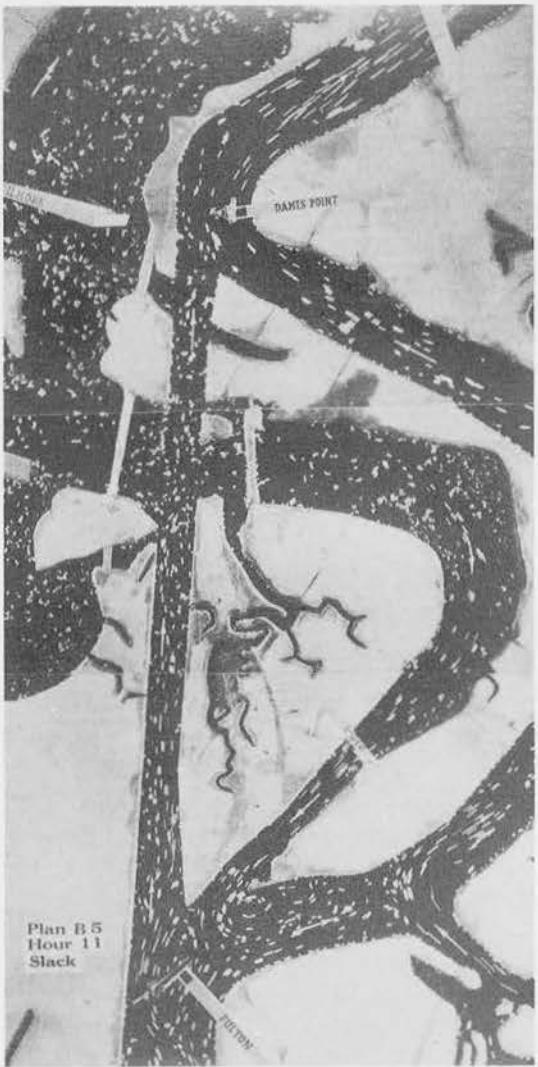
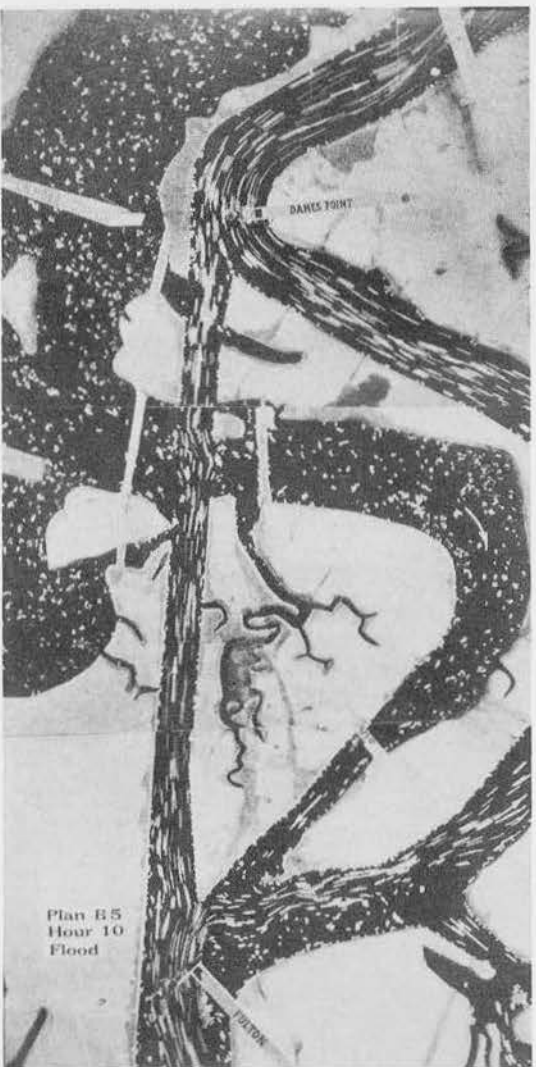








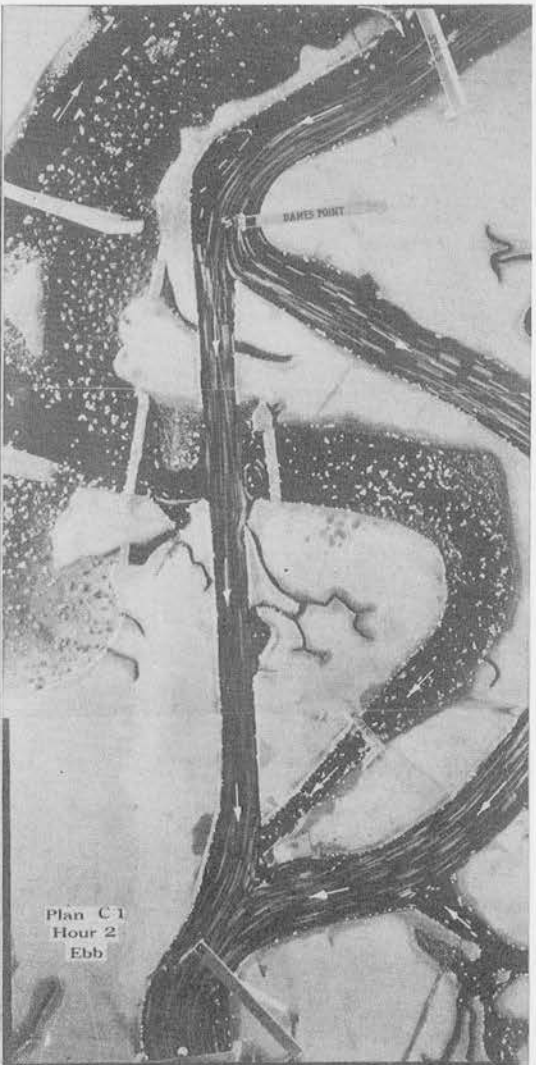
PHOTOGRAPH 27







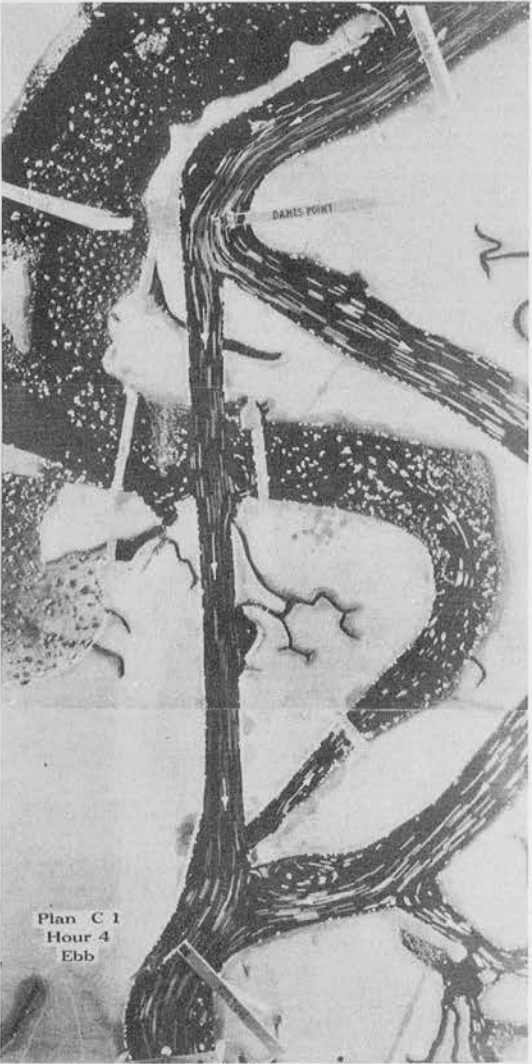
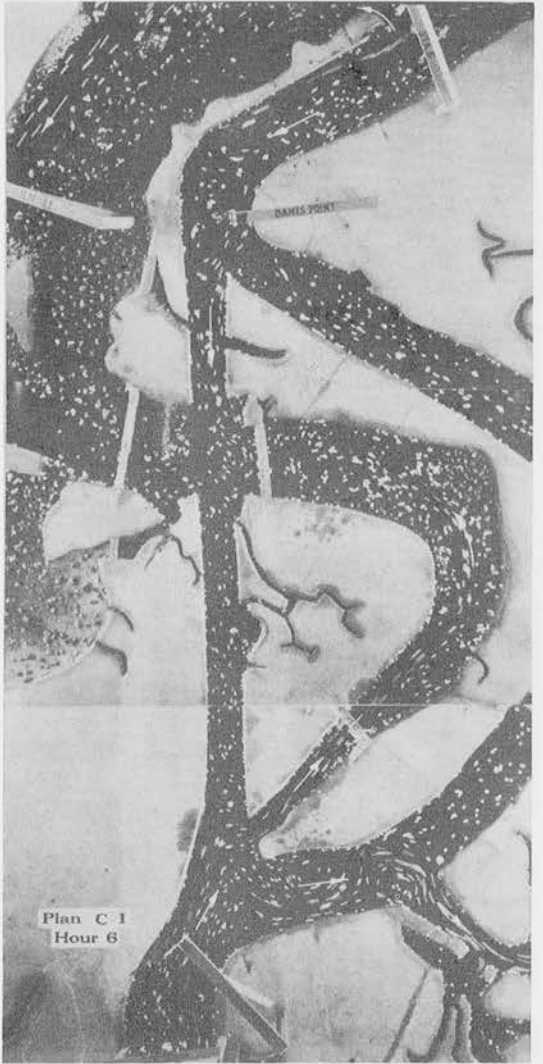
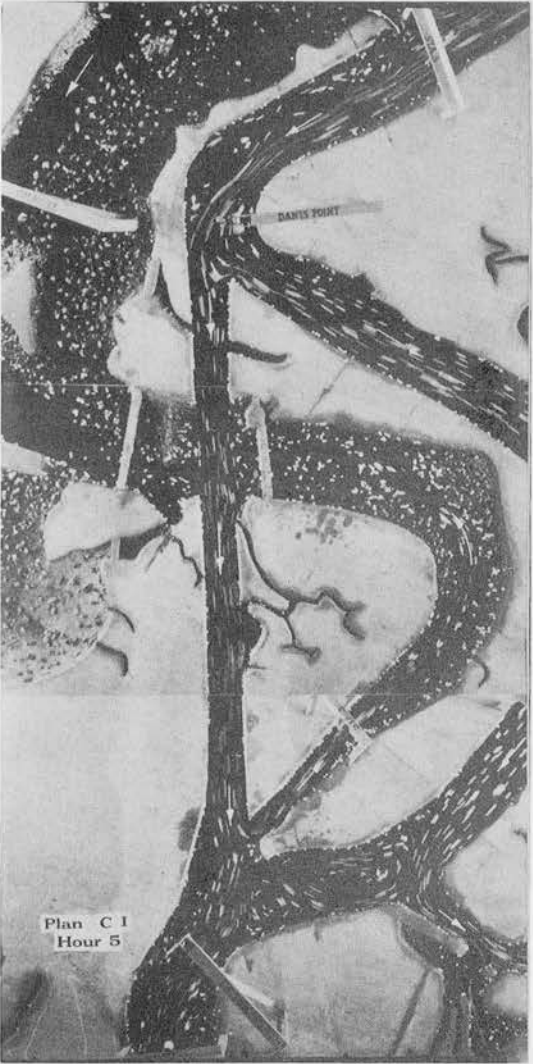
Plan C 1  
Hour 3  
Ebb

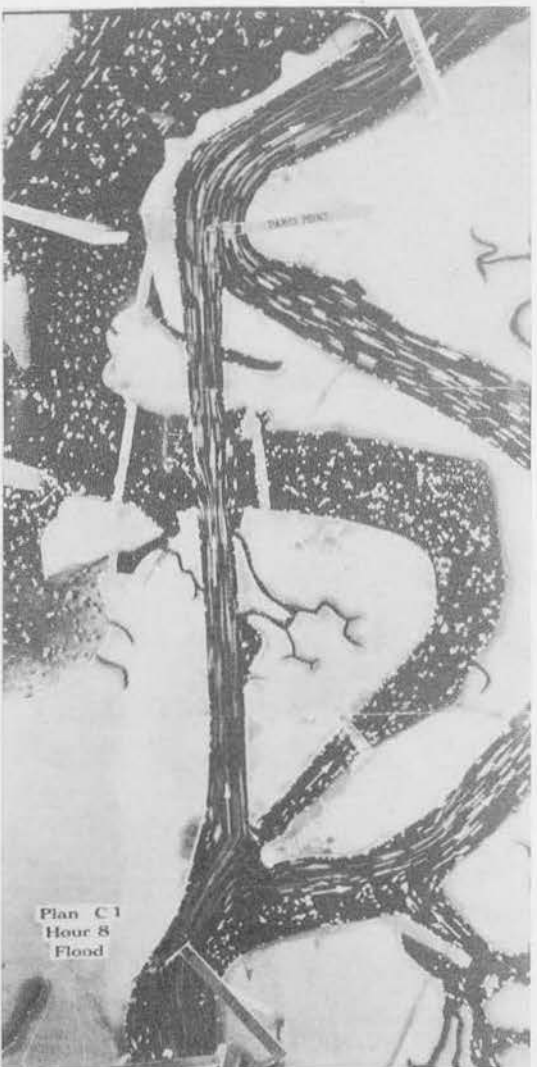


Plan C 1  
Hour 2  
Ebb

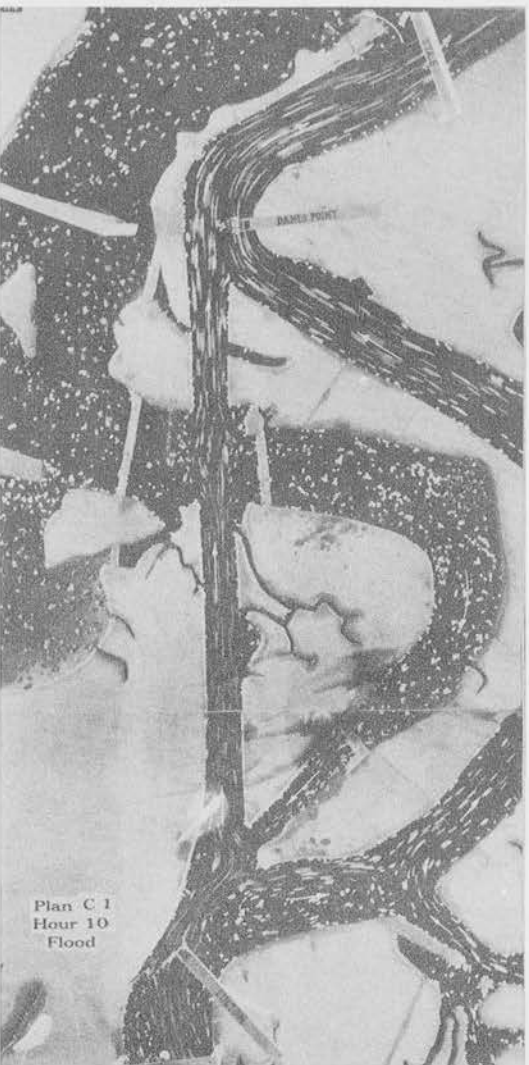


Plan C 1  
Hour 1  
Ebb

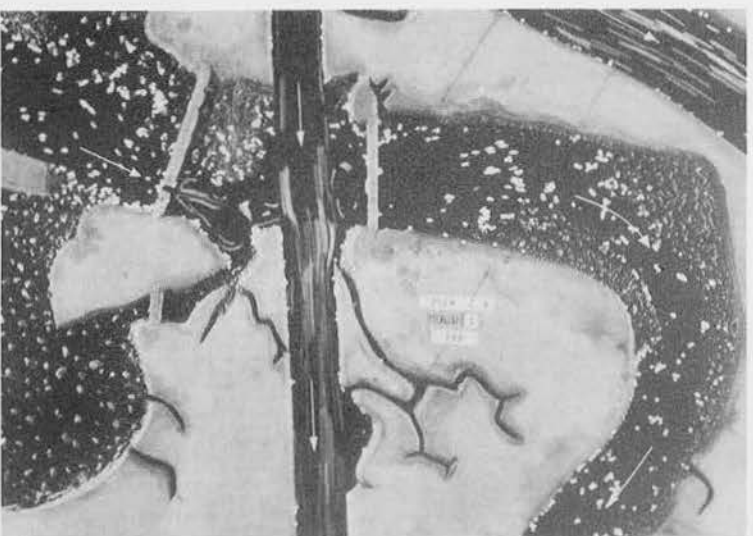
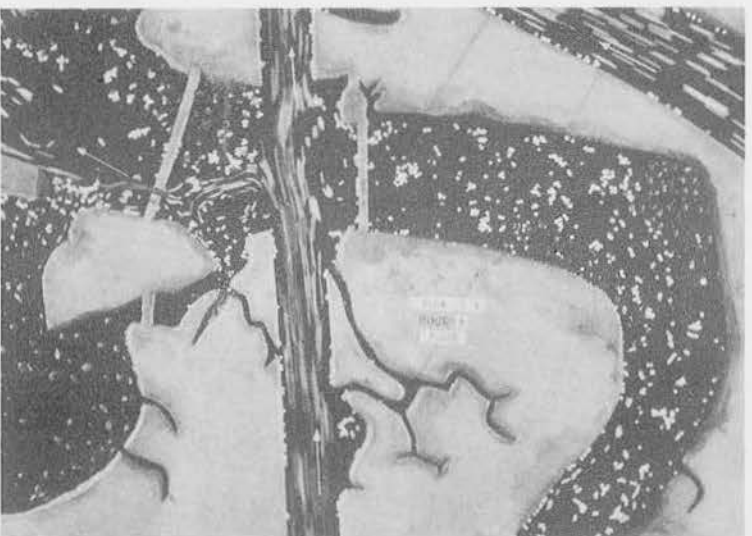




PHOTOGRAPH 31



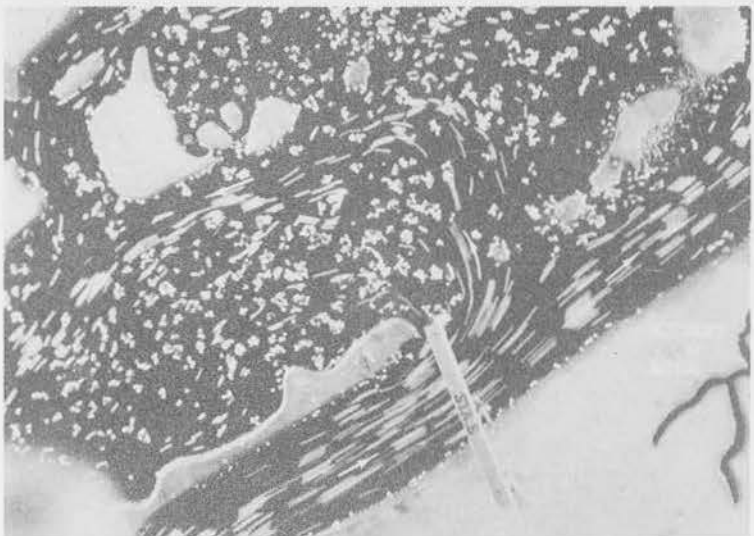




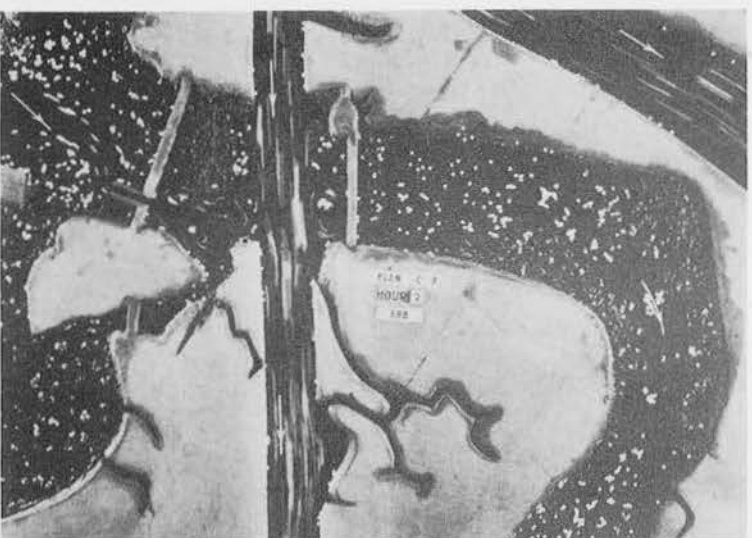
PHOTOGRAPH 33



PHOTOGRAPH 34

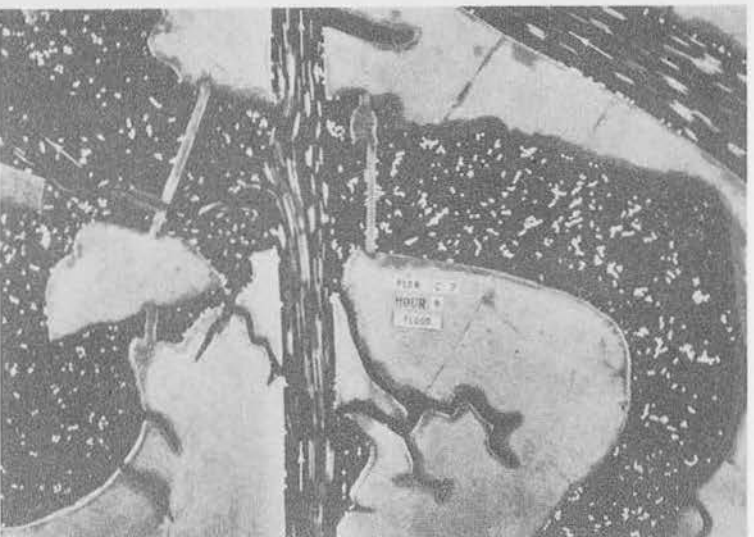
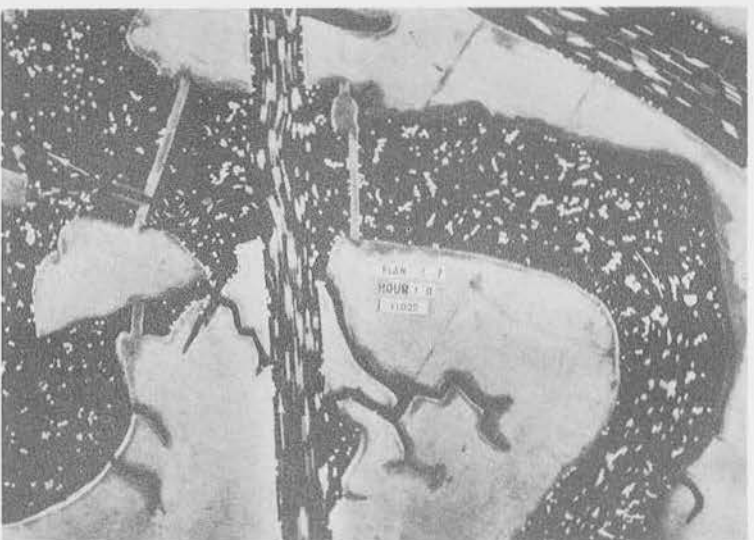


PHOTOGRAPH 35



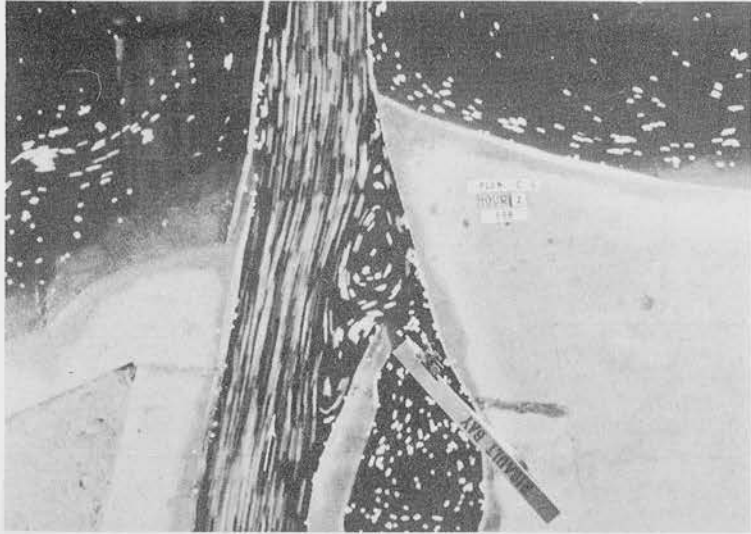
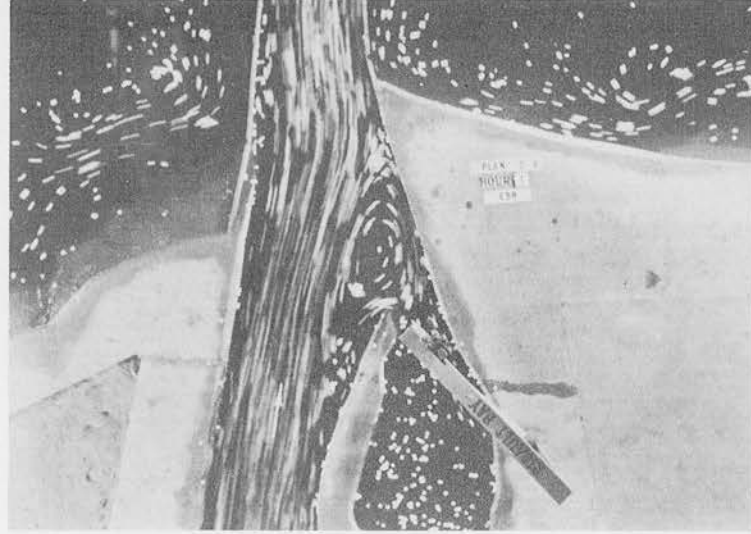
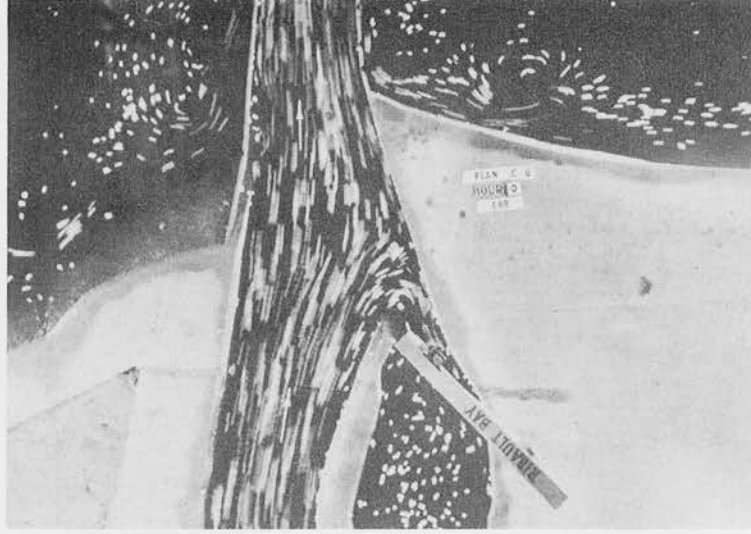
PHOTOGRAPH 36

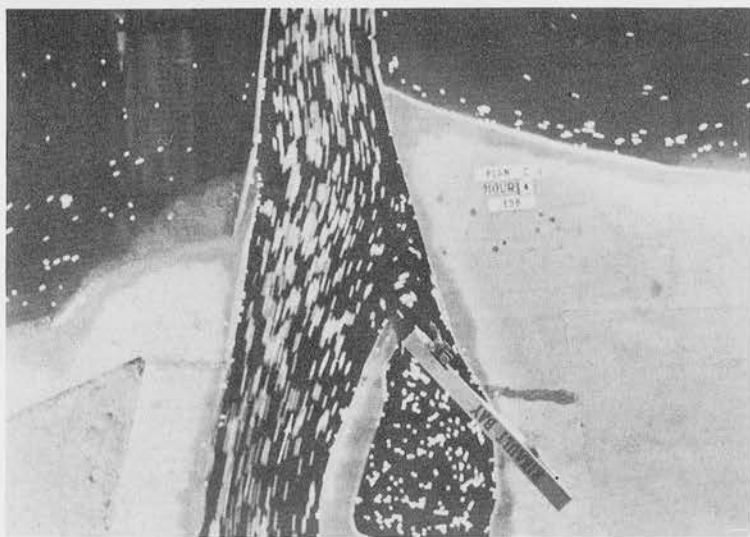
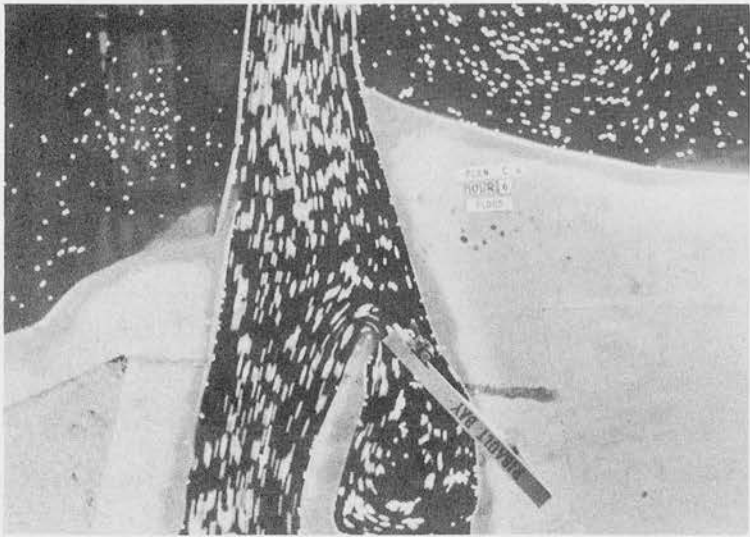
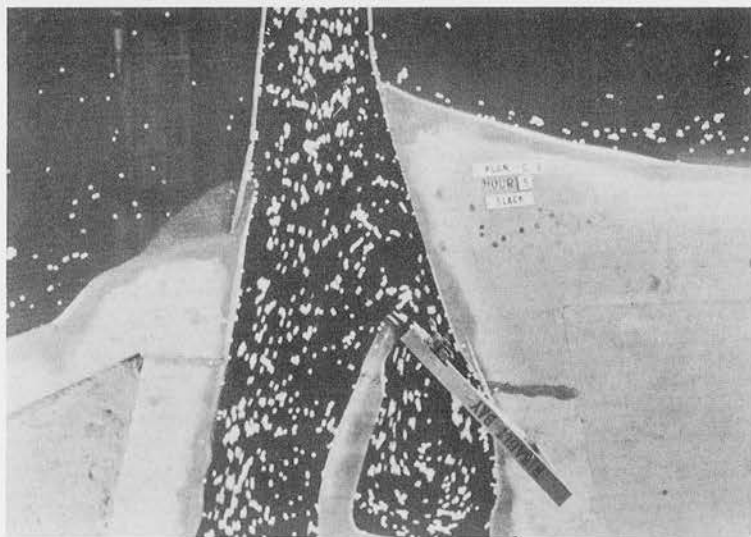
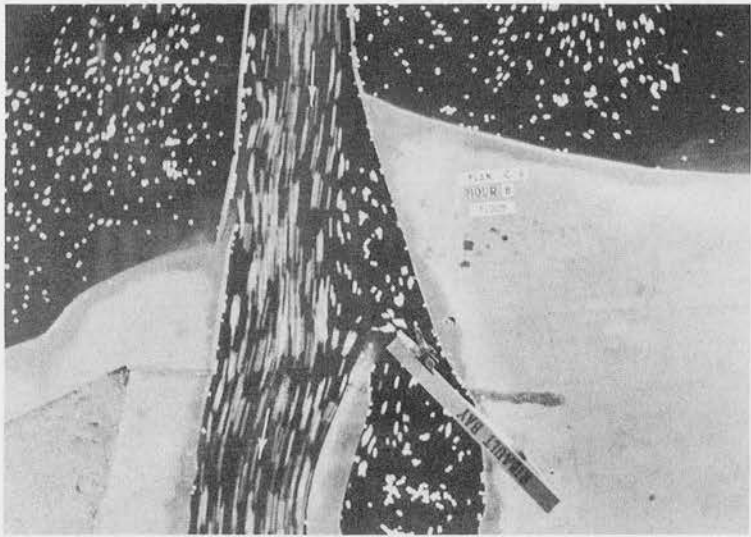




PHOTOGRAPH 37

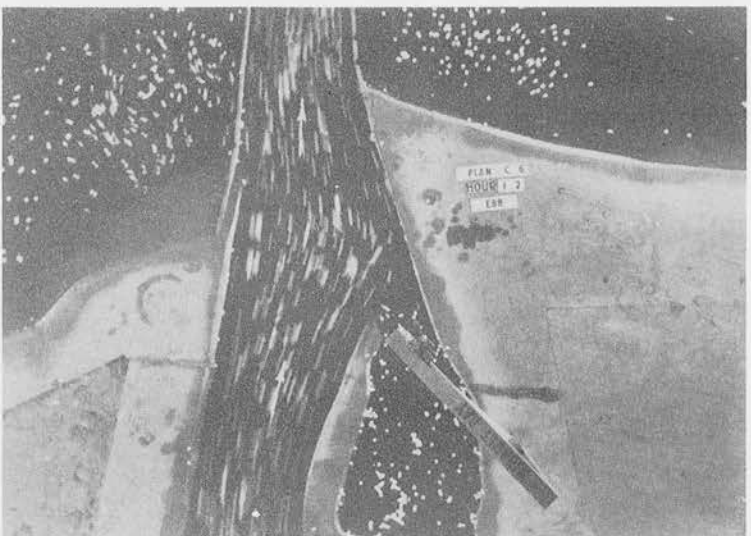
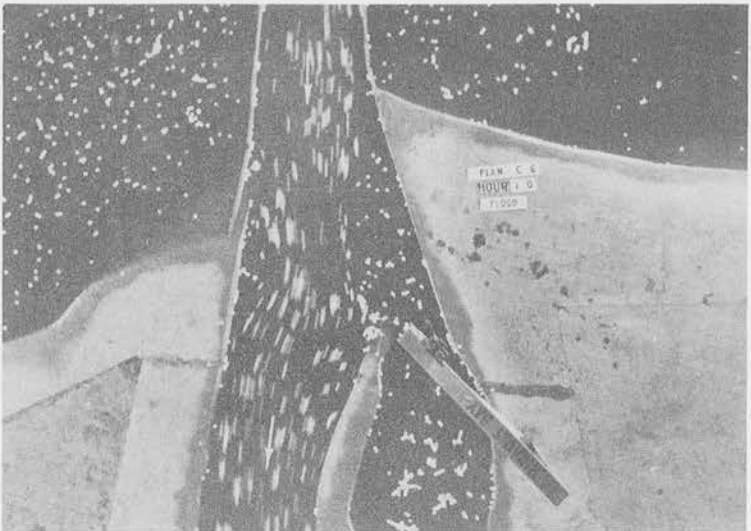
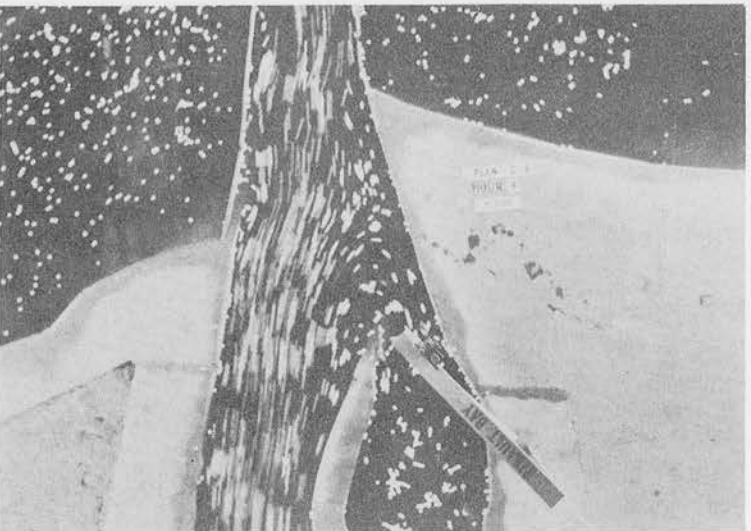
PHOTOGRAPH 38



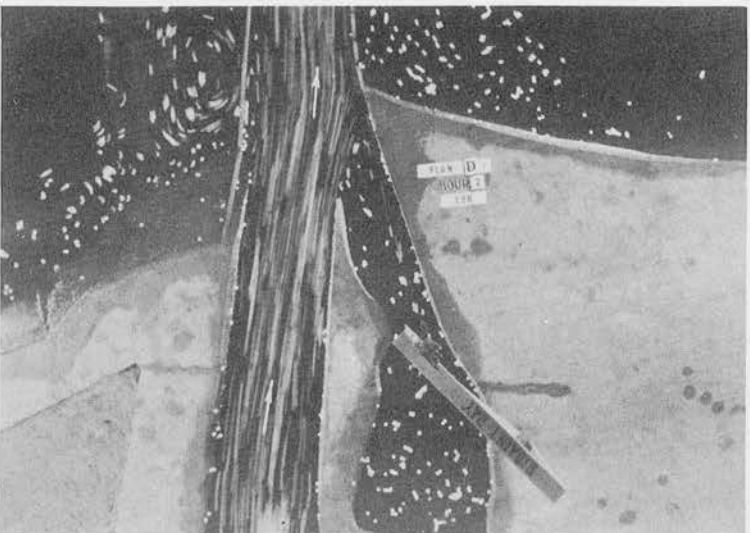
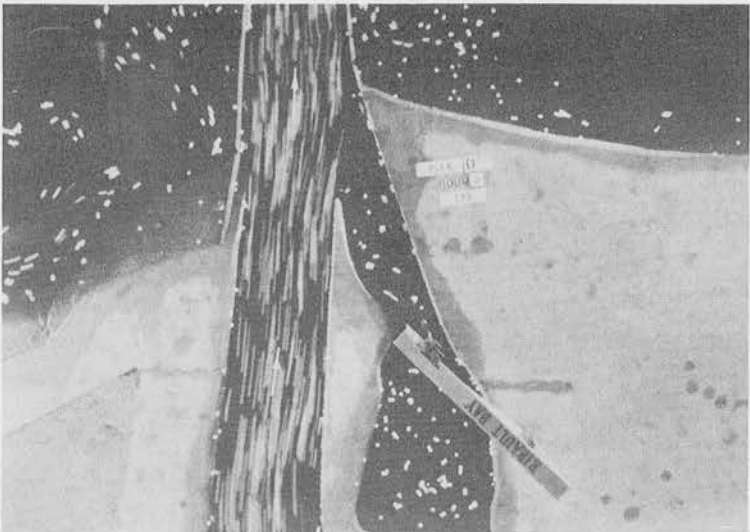
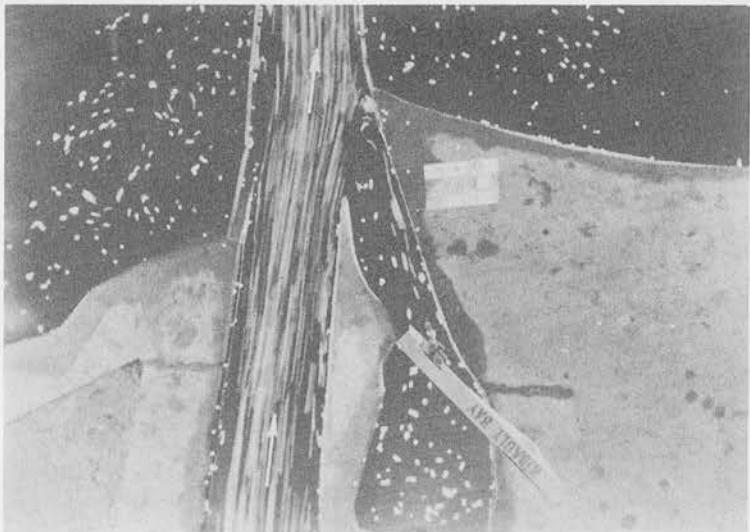


PHOTOGRAPH 39

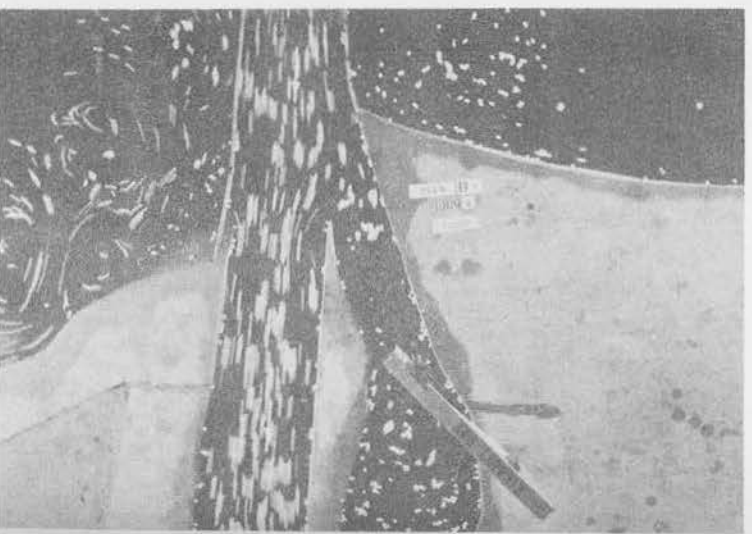
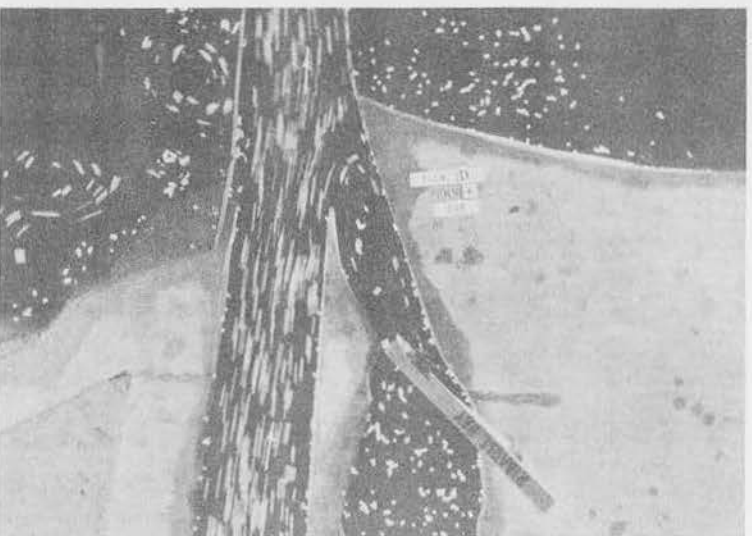
PHOTOGRAPH 40



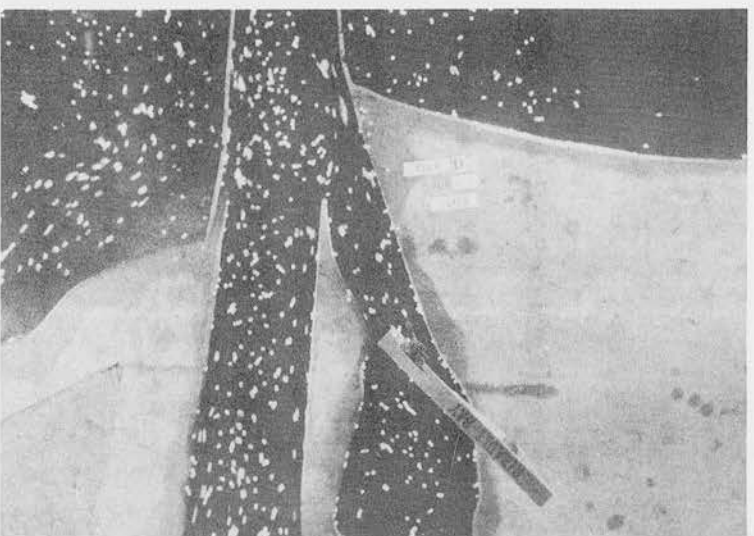
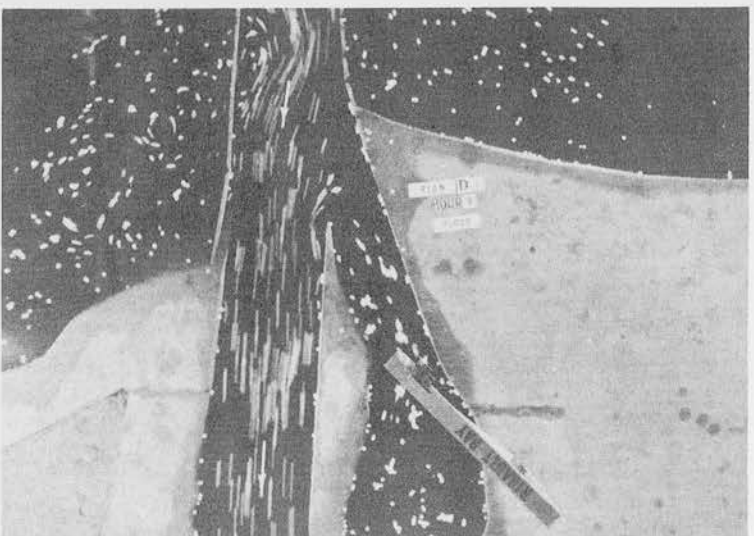
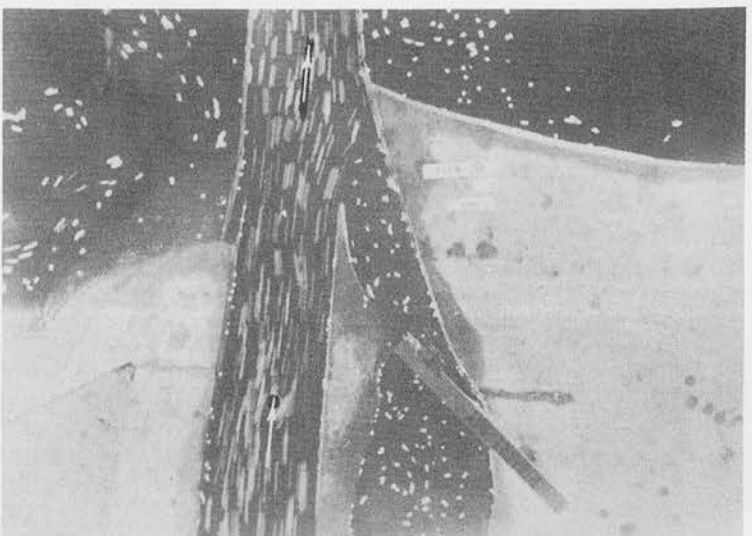
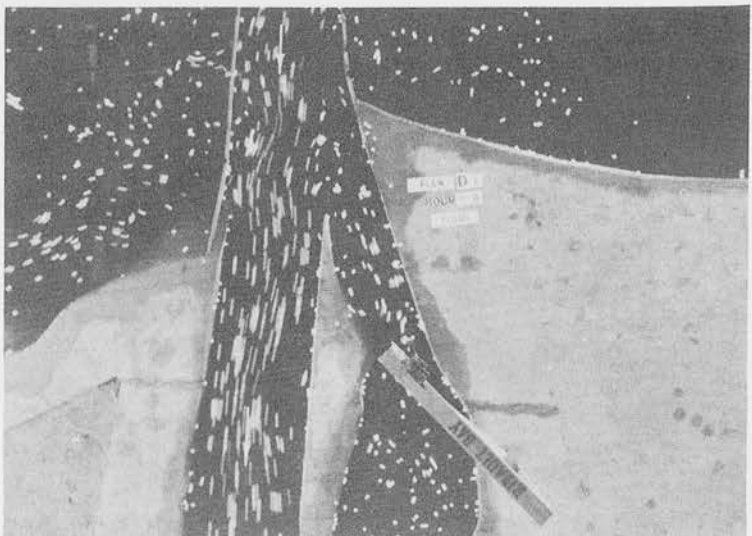




PHOTOGRAPH 41

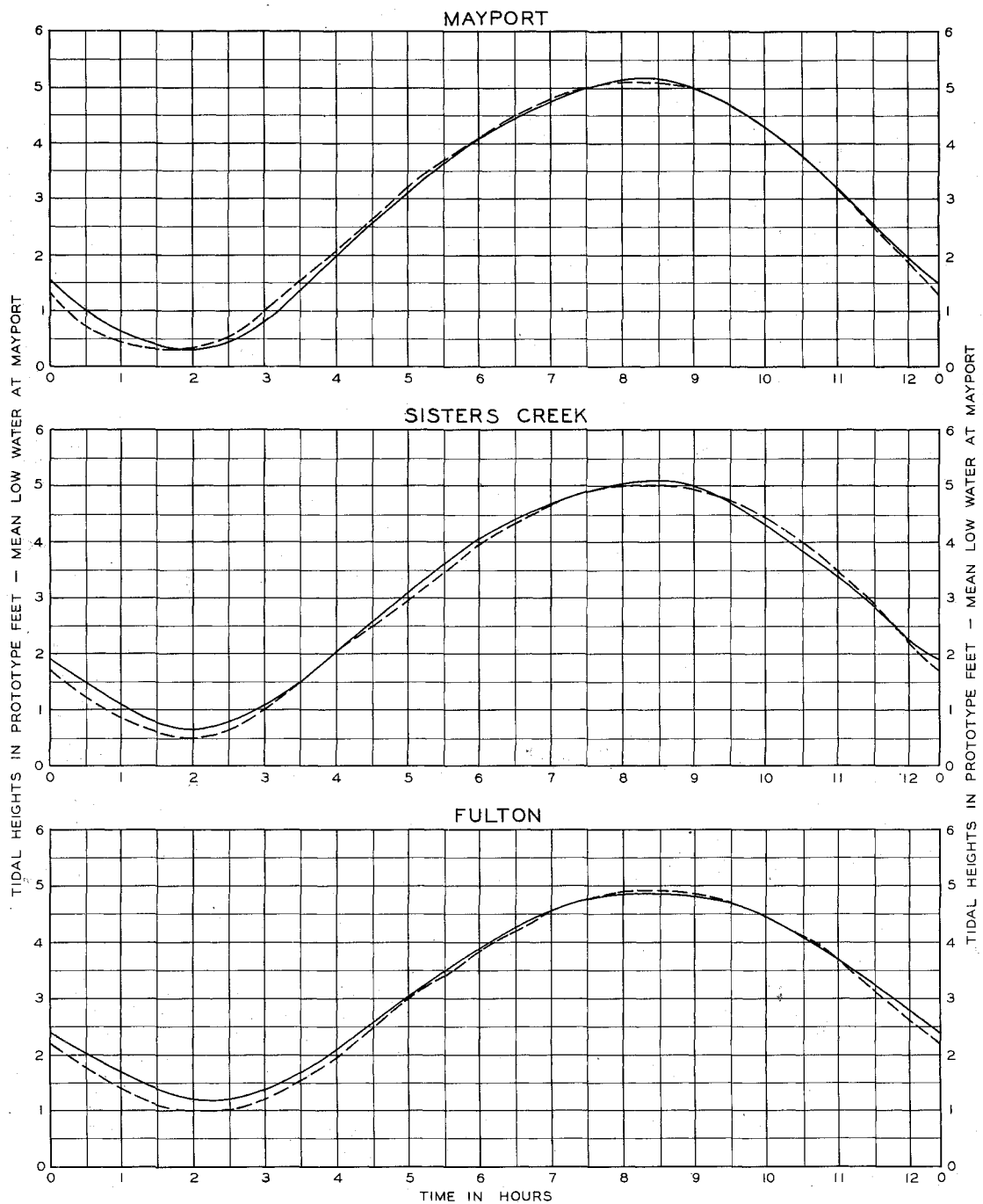


PHOTOGRAPH 42



## PLATES





#### TEST DATA

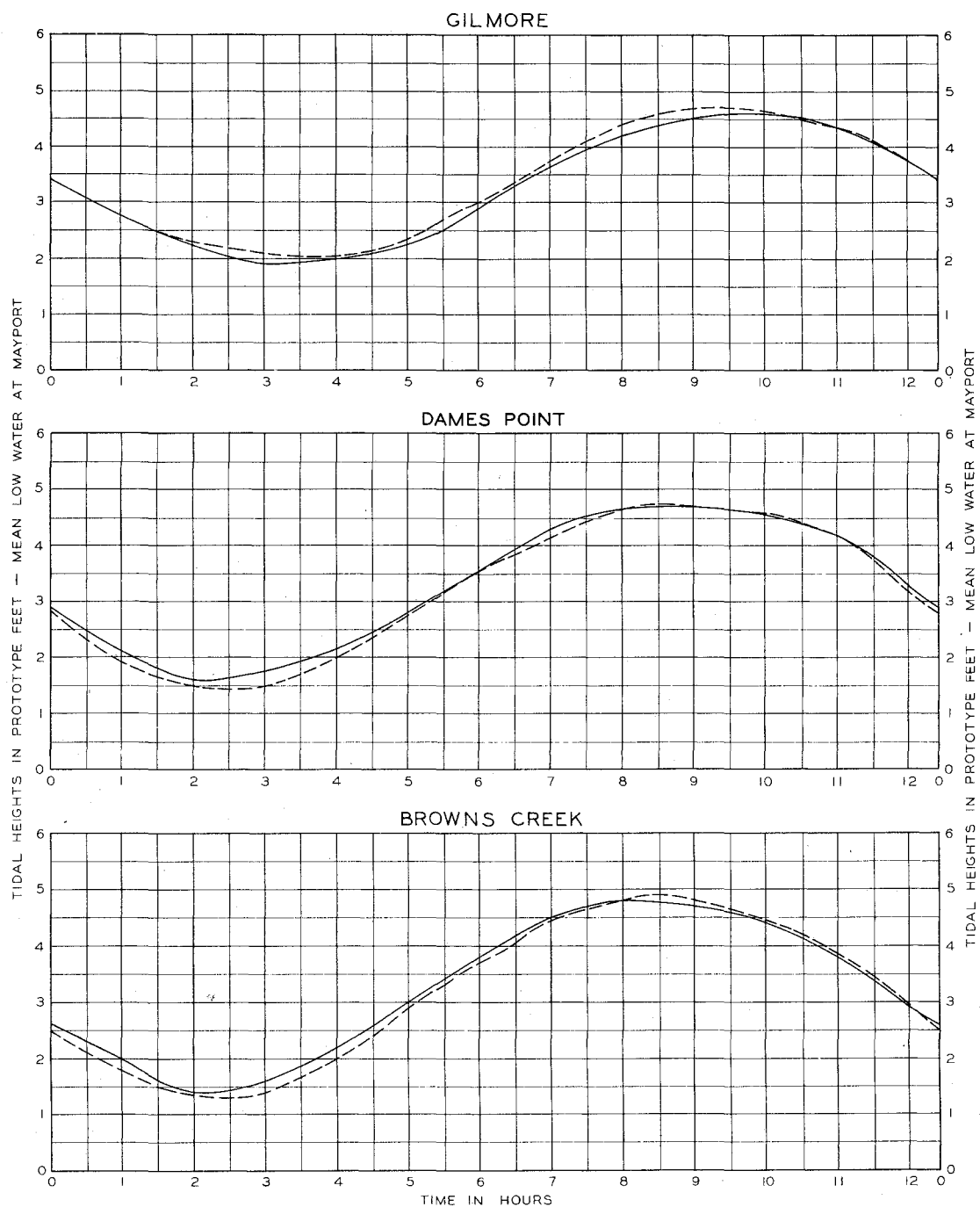
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

———— PROTOTYPE TIDAL HEIGHTS  
----- MODEL TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
VERIFICATION



#### TEST DATA

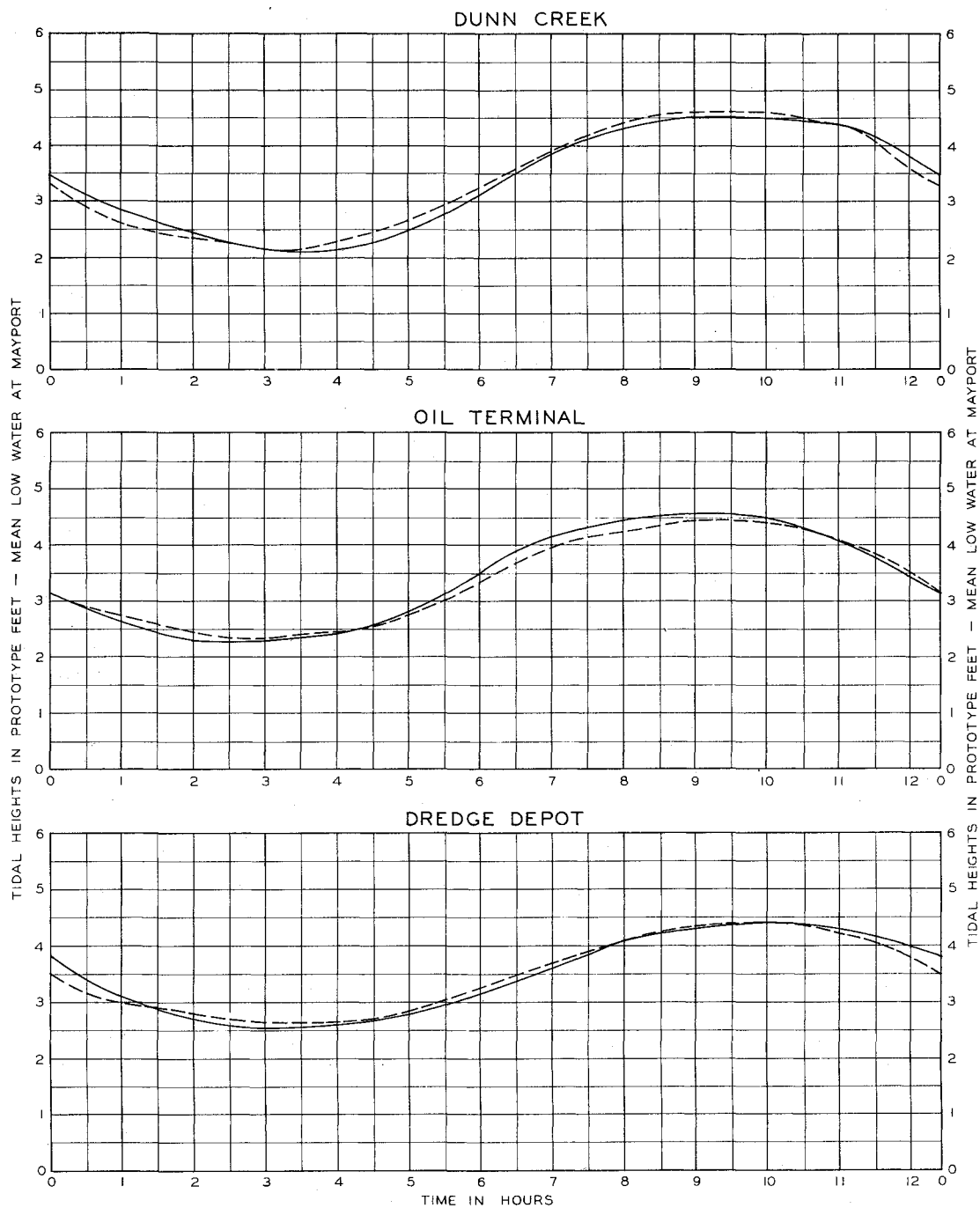
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

—— PROTOTYPE TIDAL HEIGHTS  
----- MODEL TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
VERIFICATION



#### TEST DATA

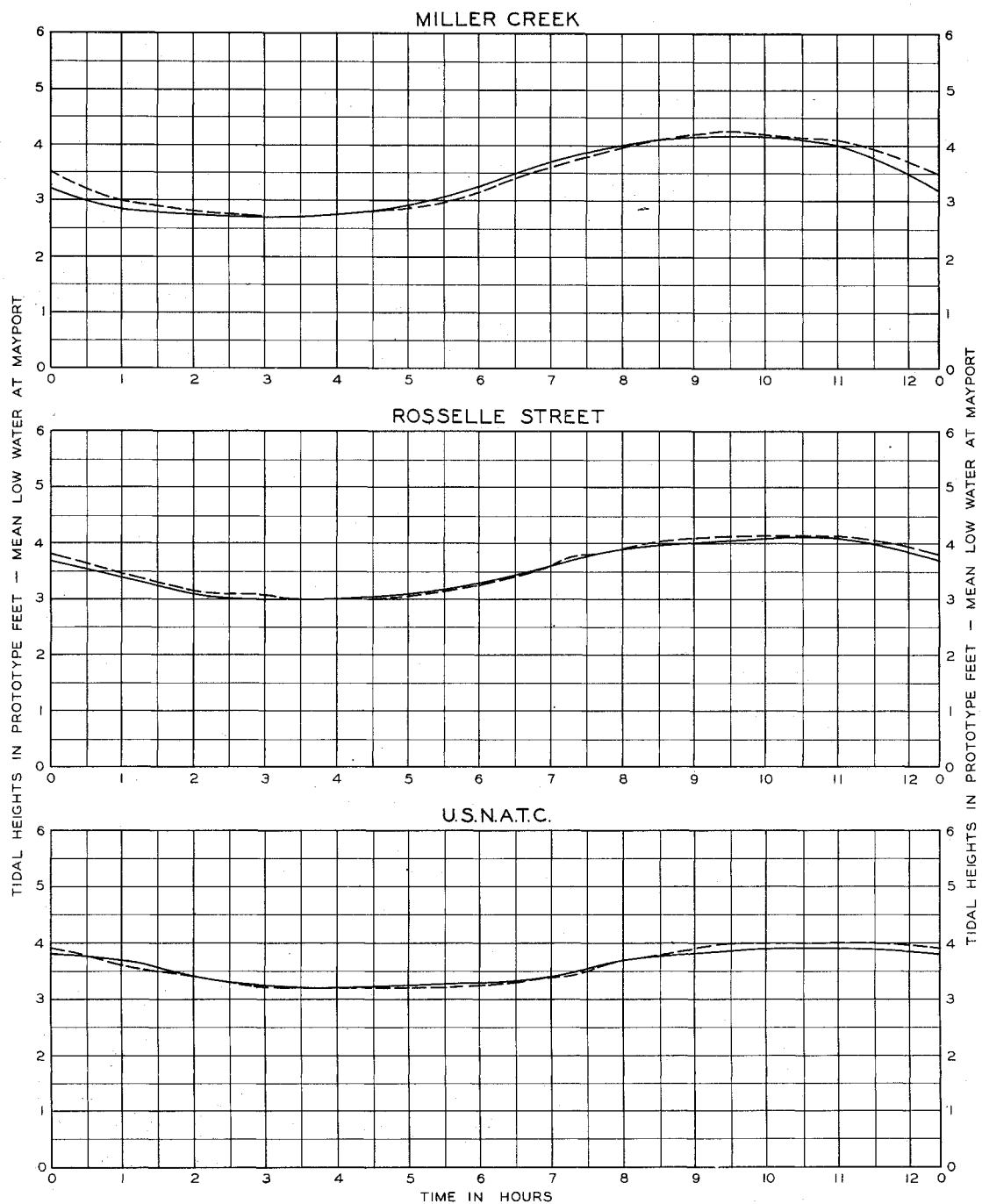
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

—— PROTOTYPE TIDAL HEIGHTS  
----- MODEL TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
VERIFICATION



#### TEST DATA

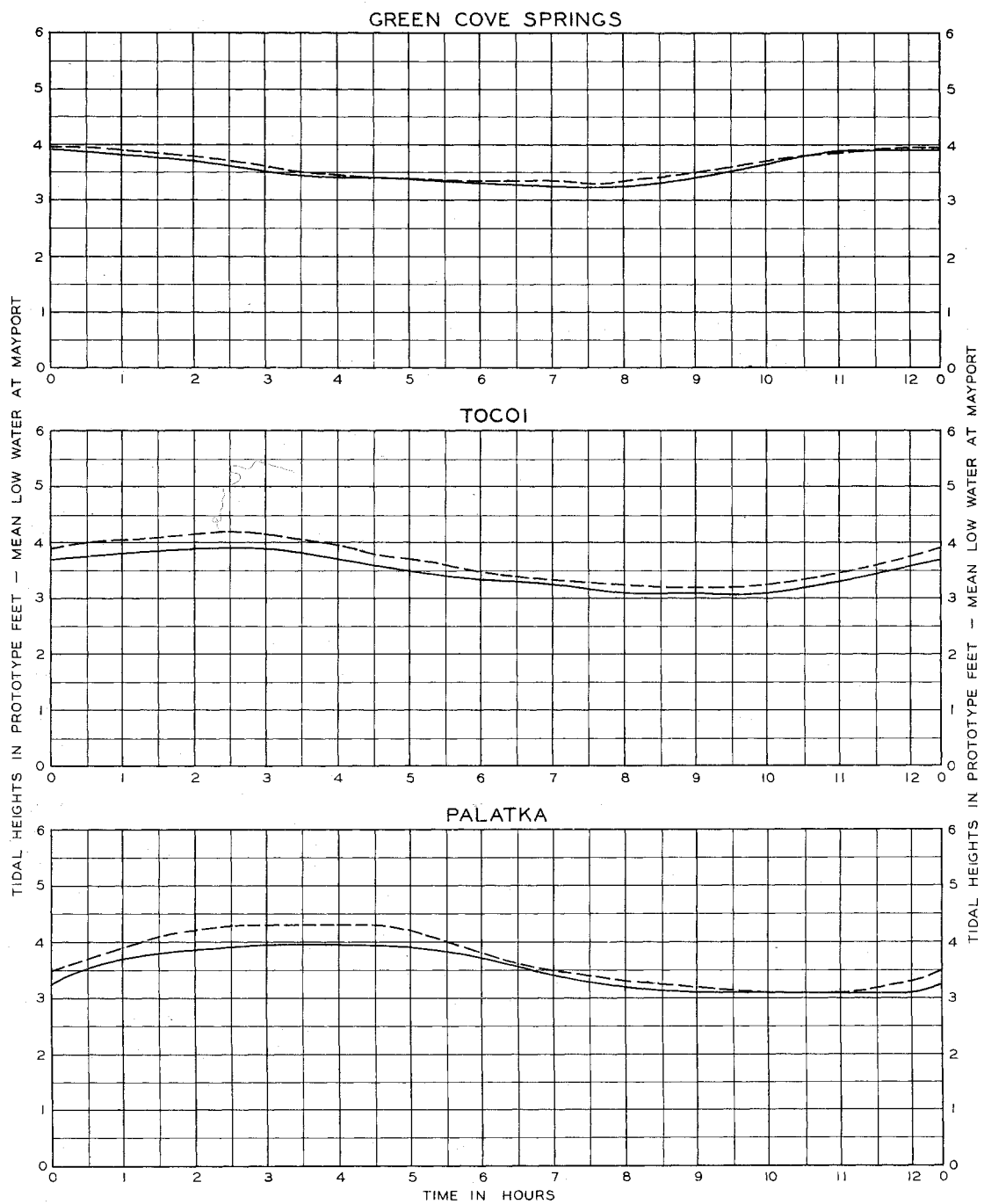
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

— PROTOTYPE TIDAL HEIGHTS  
- - - MODEL TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
VERIFICATION



#### TEST DATA

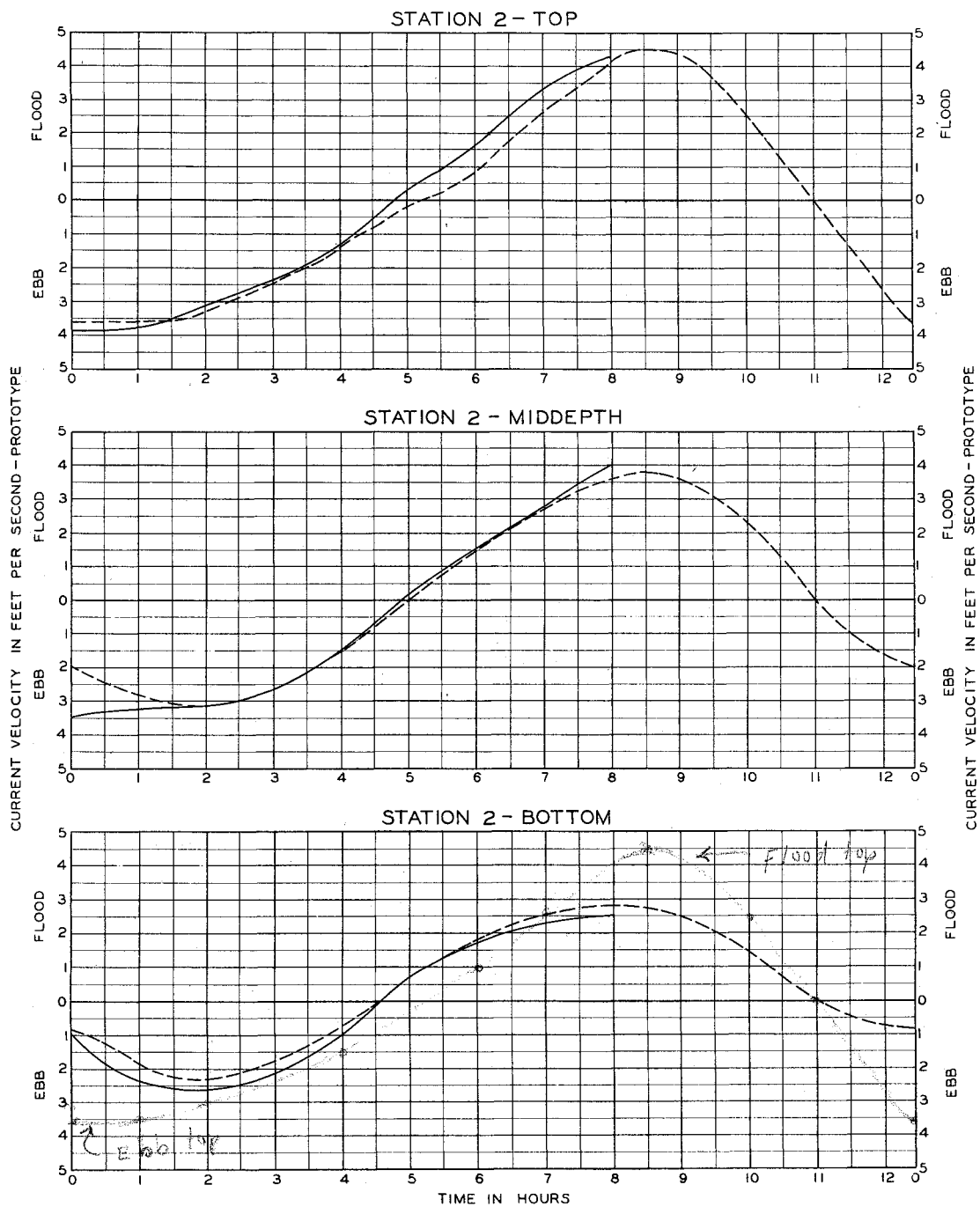
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

— PROTOTYPE TIDAL HEIGHTS  
- - - MODEL TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
VERIFICATION



#### TEST DATA

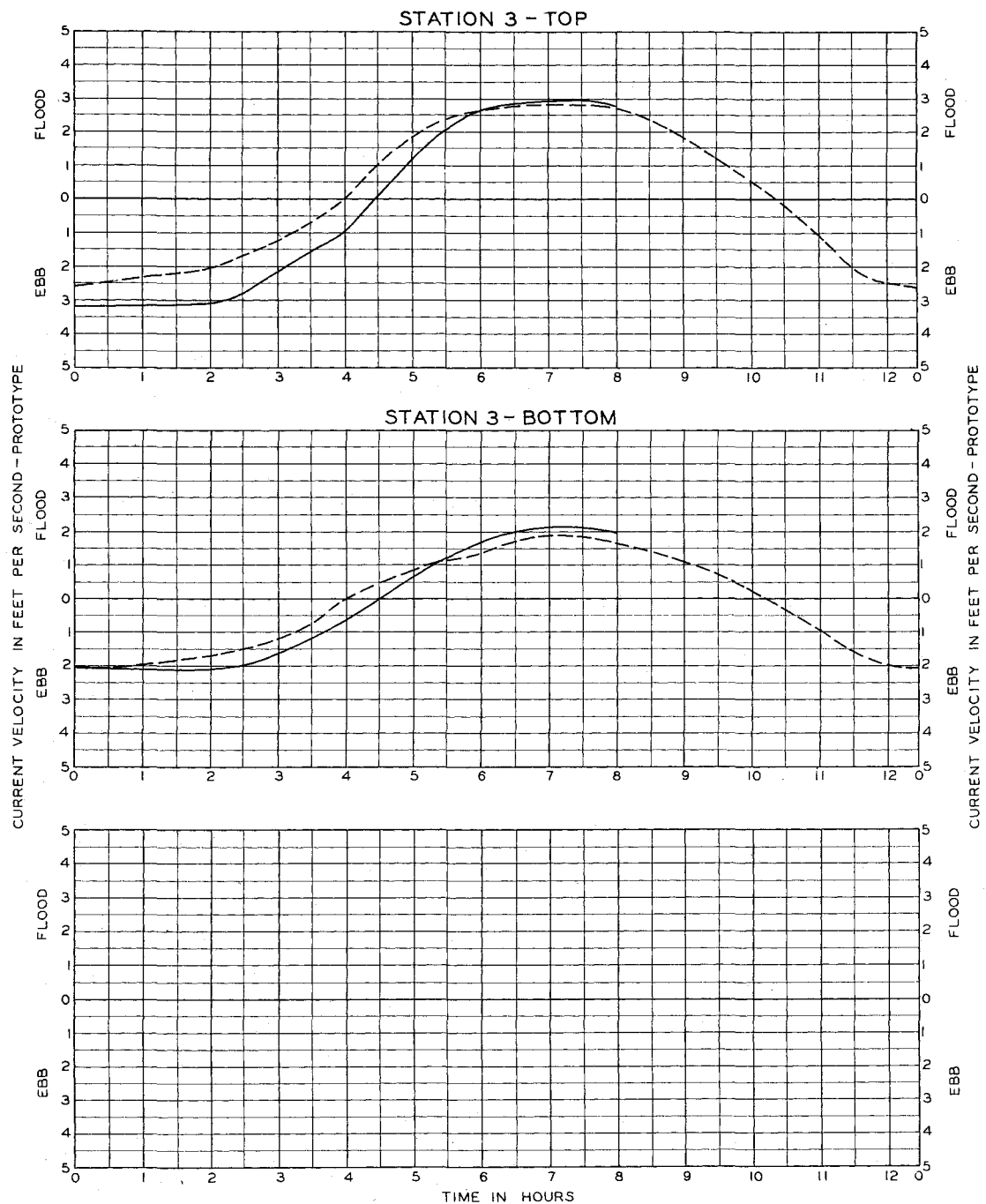
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

—— PROTOTYPE VELOCITY CURVES  
----- MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION



#### TEST DATA

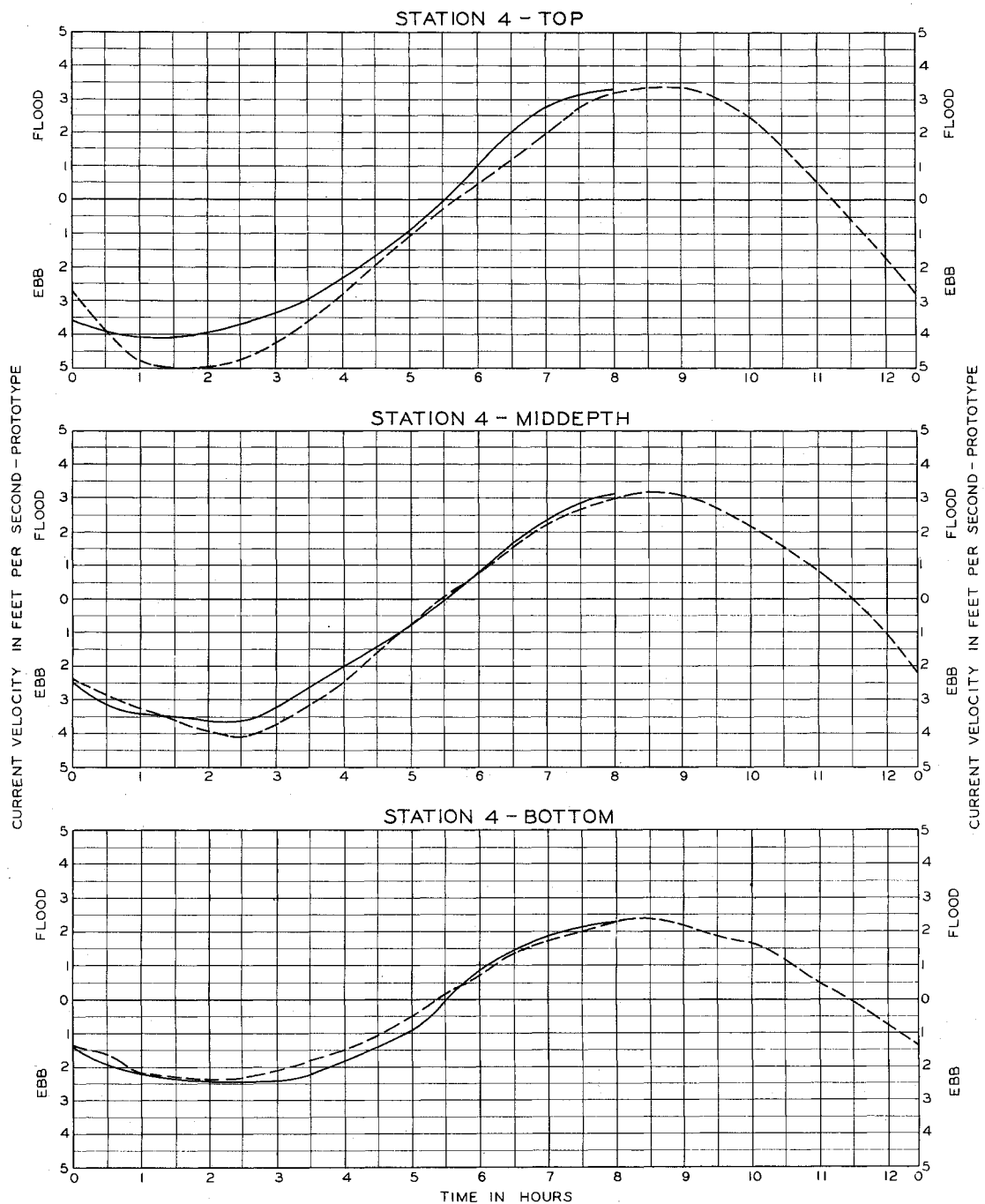
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

— PROTOTYPE VELOCITY CURVES  
- - - MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION



#### TEST DATA

RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

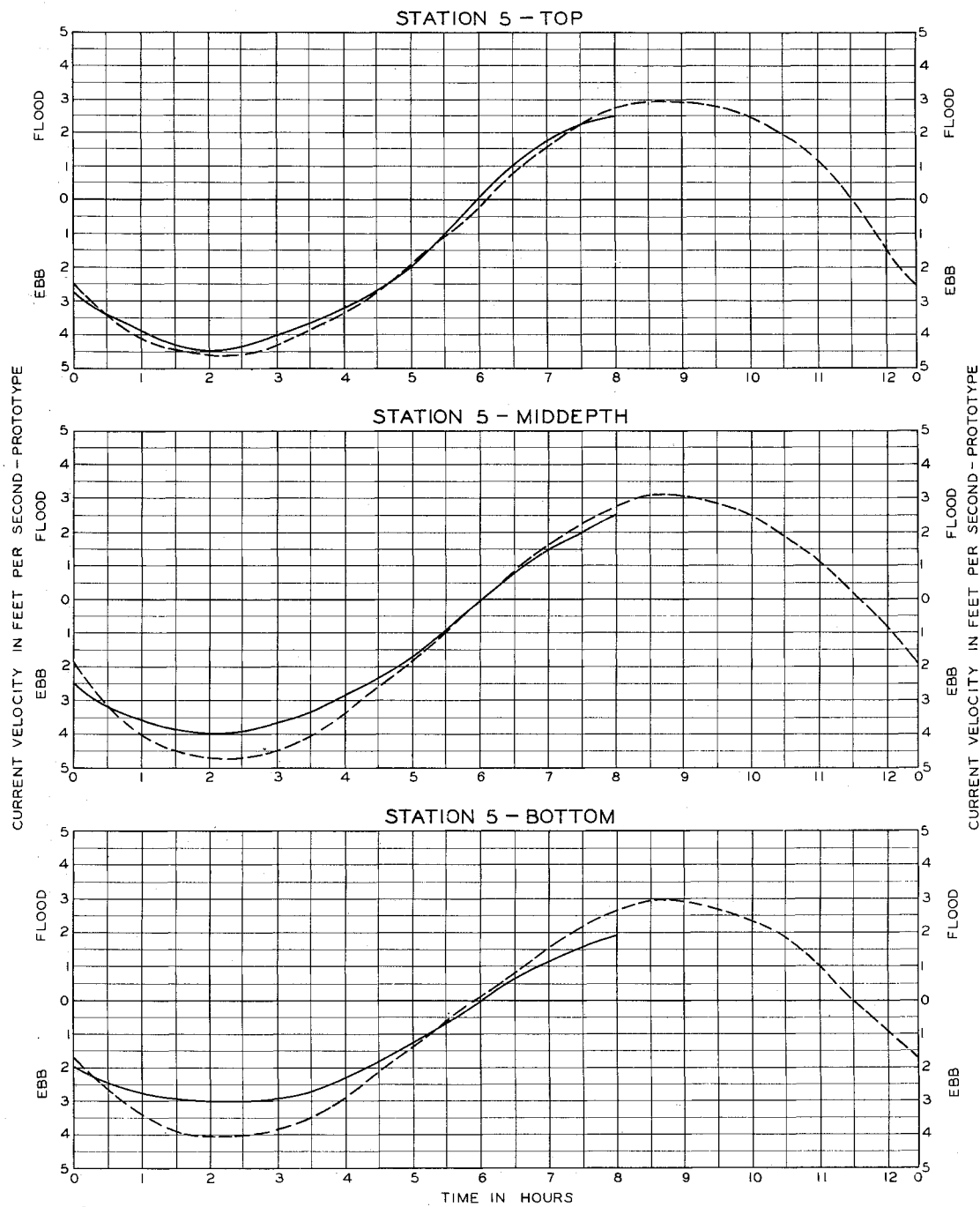
#### LEGEND

—— PROTOTYPE VELOCITY CURVES  
- - - - MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION





#### TEST DATA

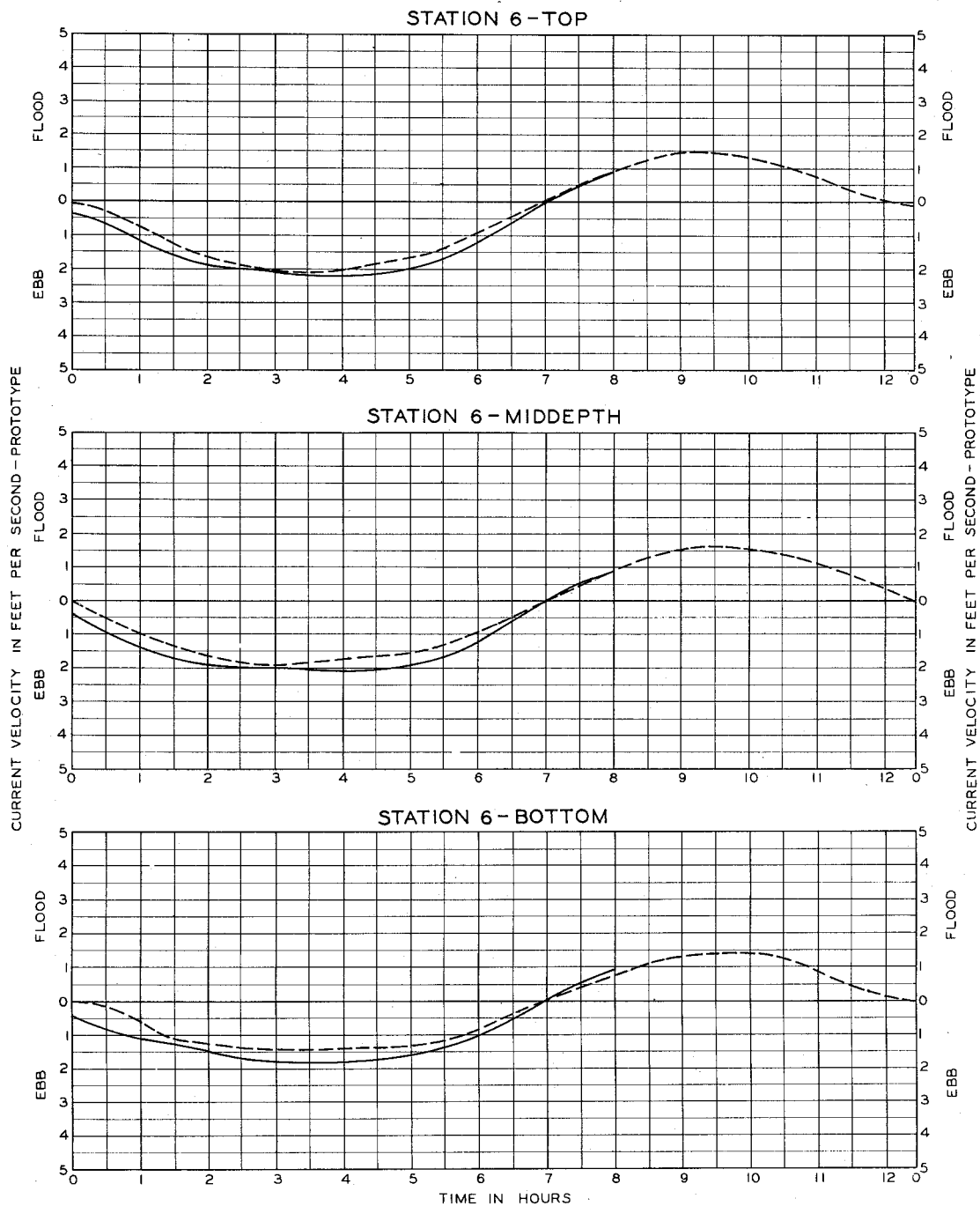
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

—— PROTOTYPE VELOCITY CURVES  
----- MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION



#### TEST DATA

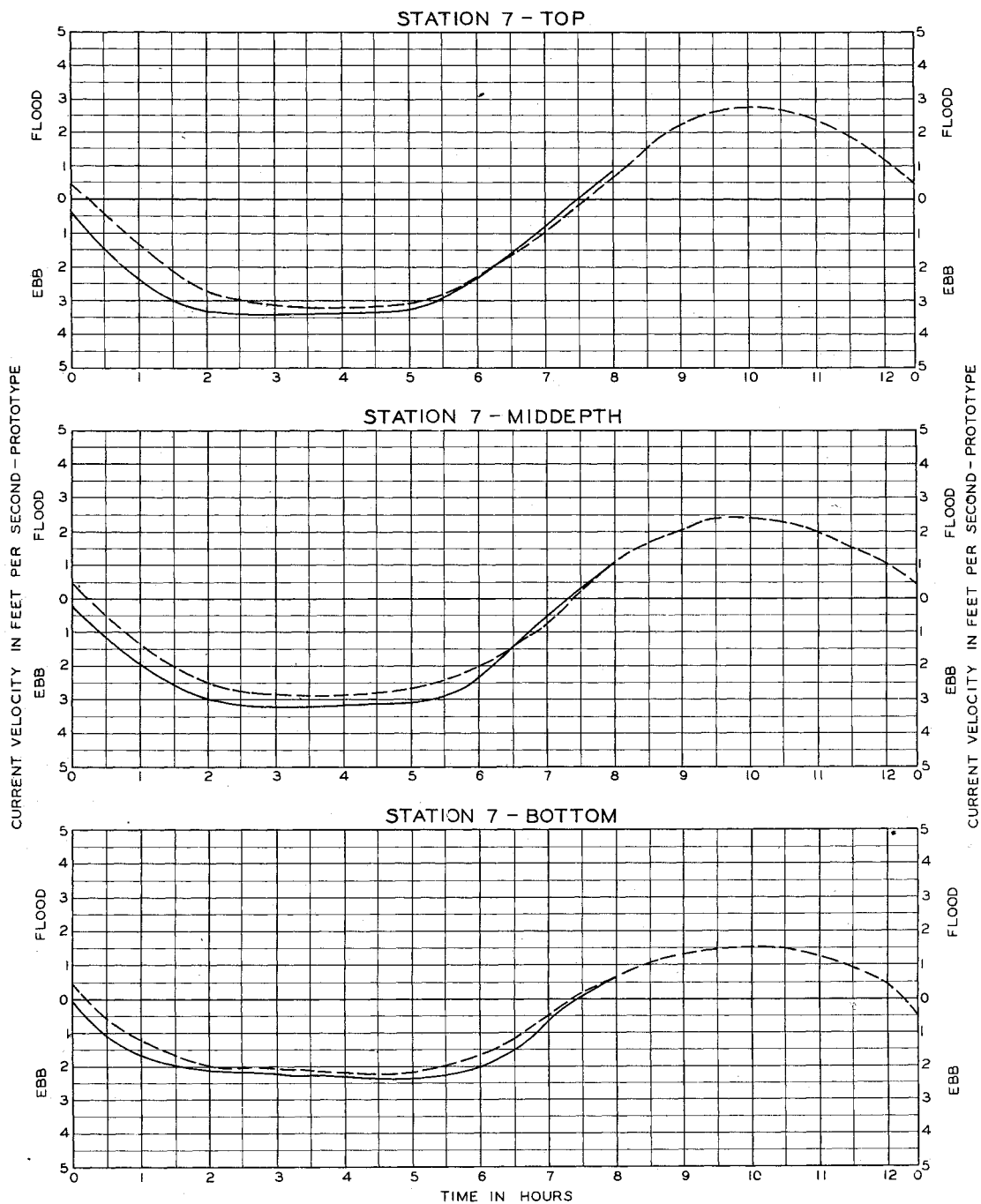
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

—— PROTOTYPE VELOCITY CURVES  
----- MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION



#### TEST DATA

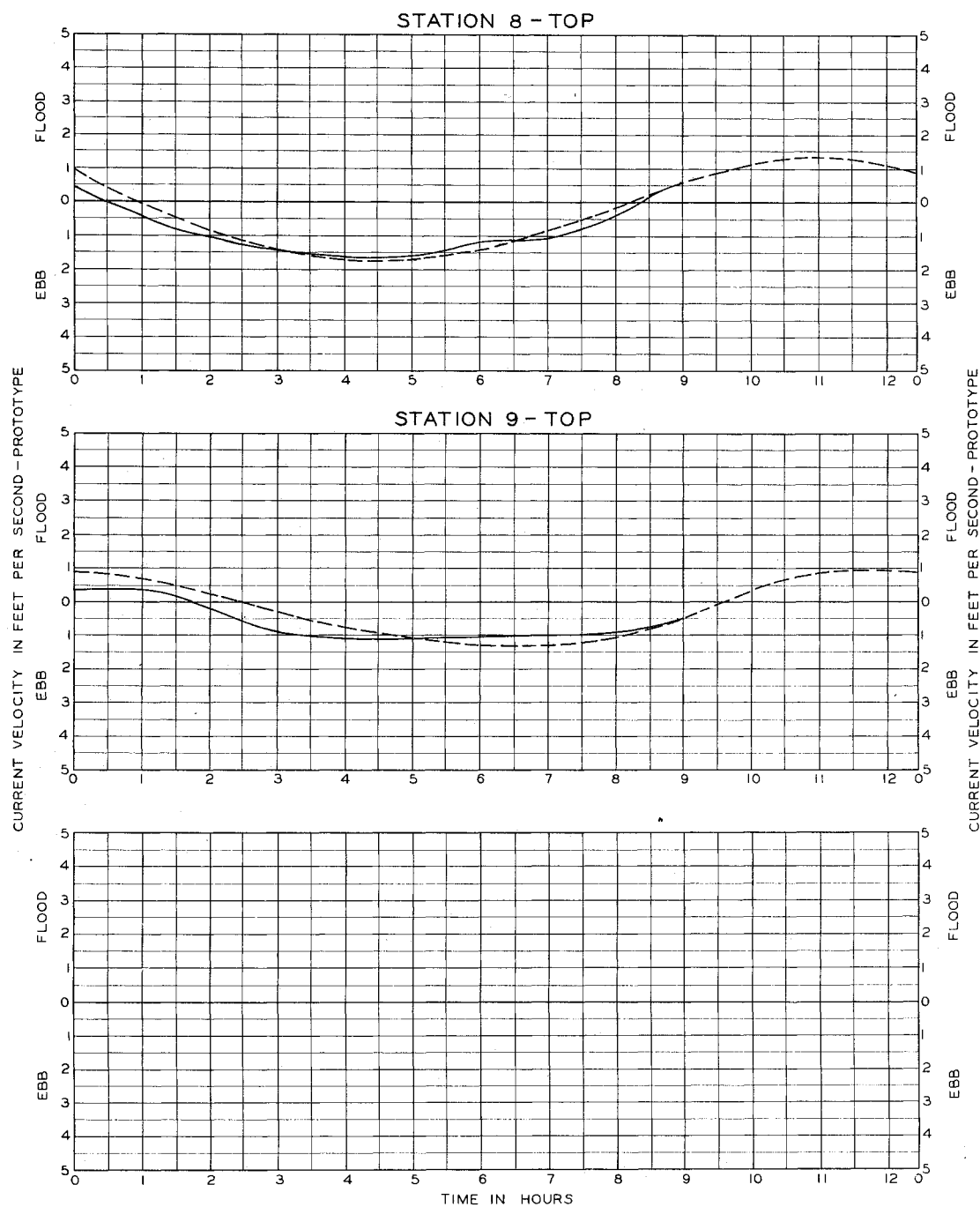
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

#### LEGEND

— PROTOTYPE VELOCITY CURVES  
- - - MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
VERIFICATION



### TEST DATA

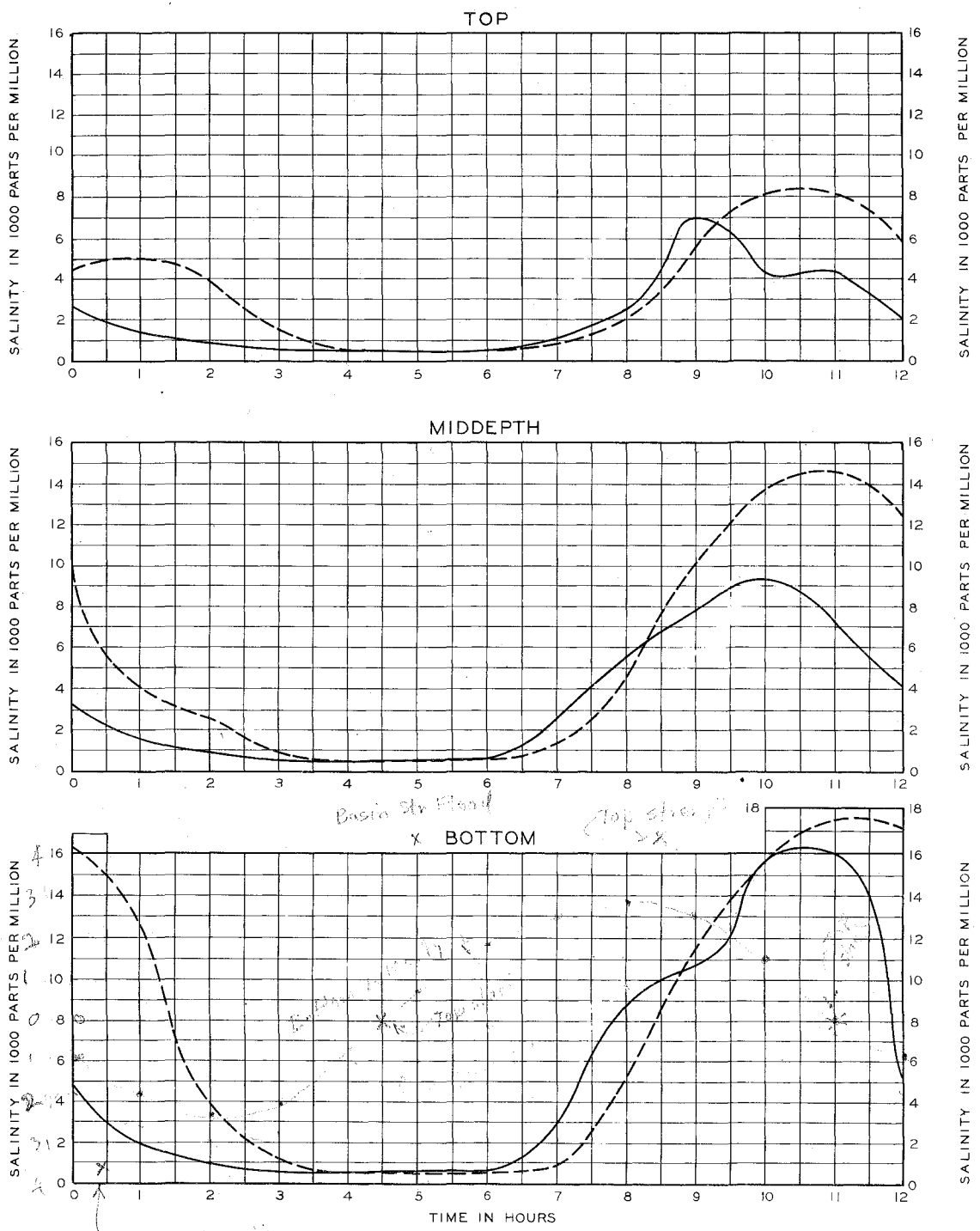
RIVER DISCHARGE 11,000 CFS  
MEAN TIDE

### LEGEND

—— PROTOTYPE VELOCITY CURVES  
----- MODEL VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

**VELOCITY CURVES  
VERIFICATION**



TEST DATA

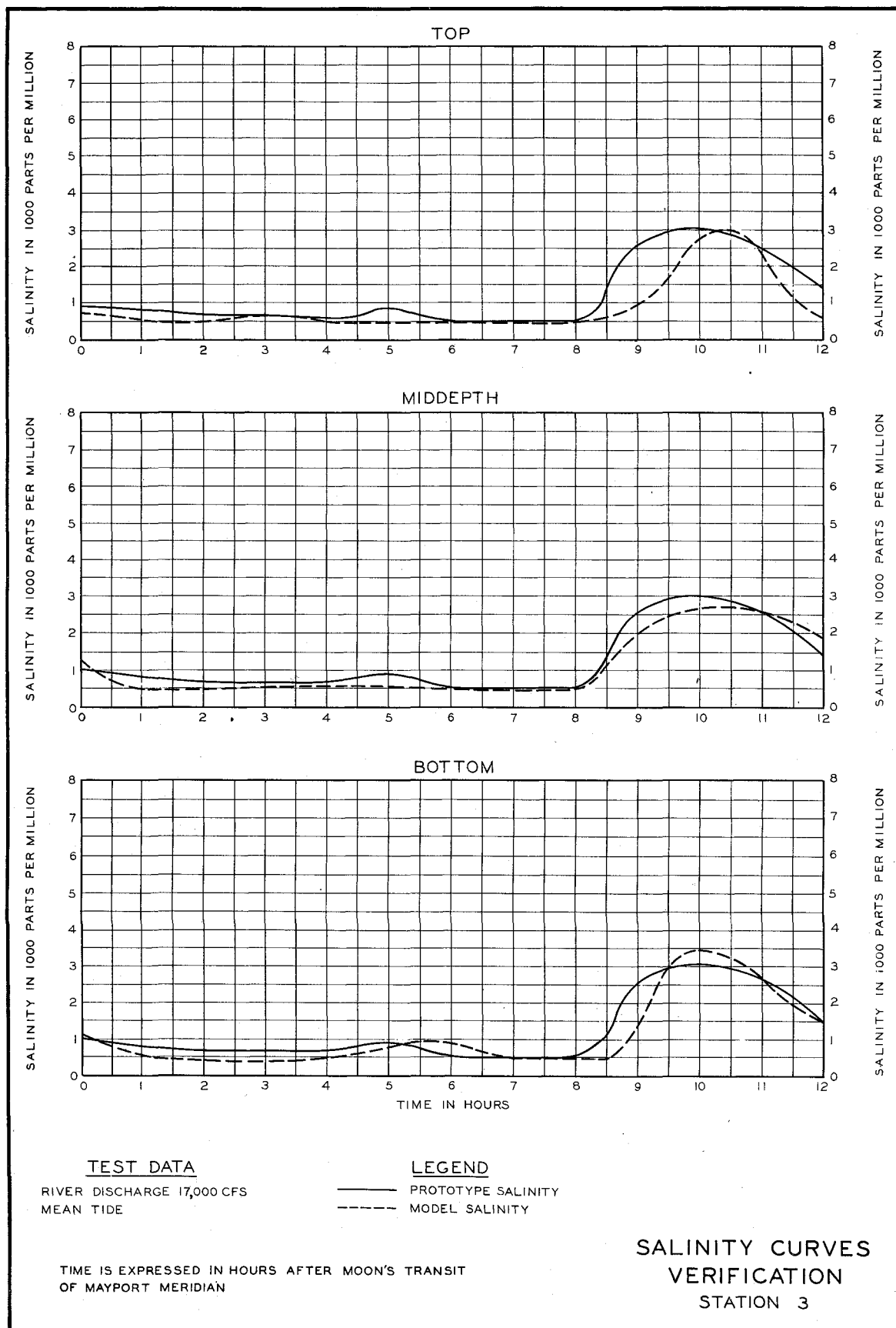
RIVER DISCHARGE 17,000 CFS  
MEAN TIDE

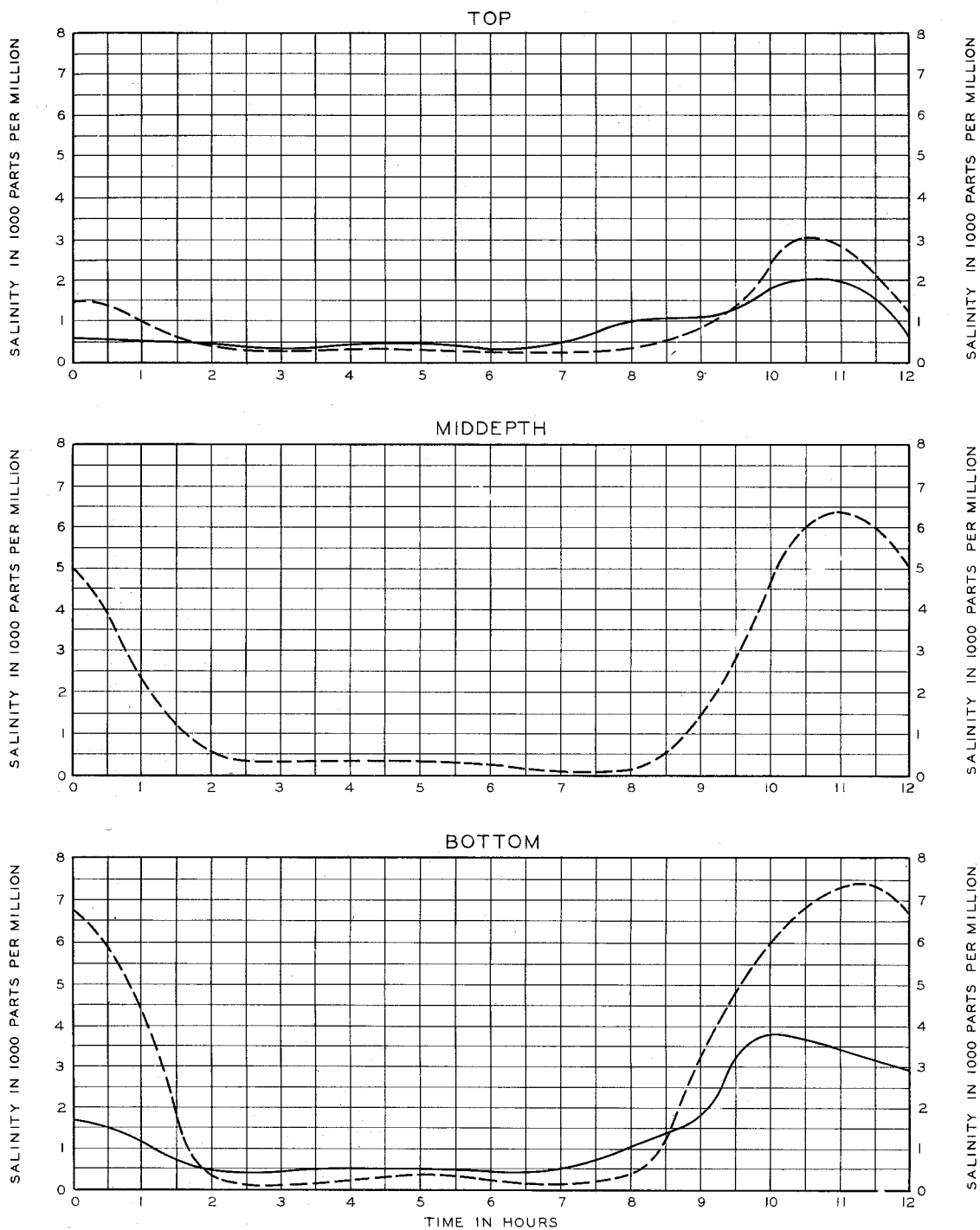
LEGEND

———— PROTOTYPE SALINITY  
----- MODEL SALINITY

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

**SALINITY CURVES  
VERIFICATION  
STATION 2**





#### TEST DATA

RIVER DISCHARGE 17,000 CFS  
MEAN TIDE

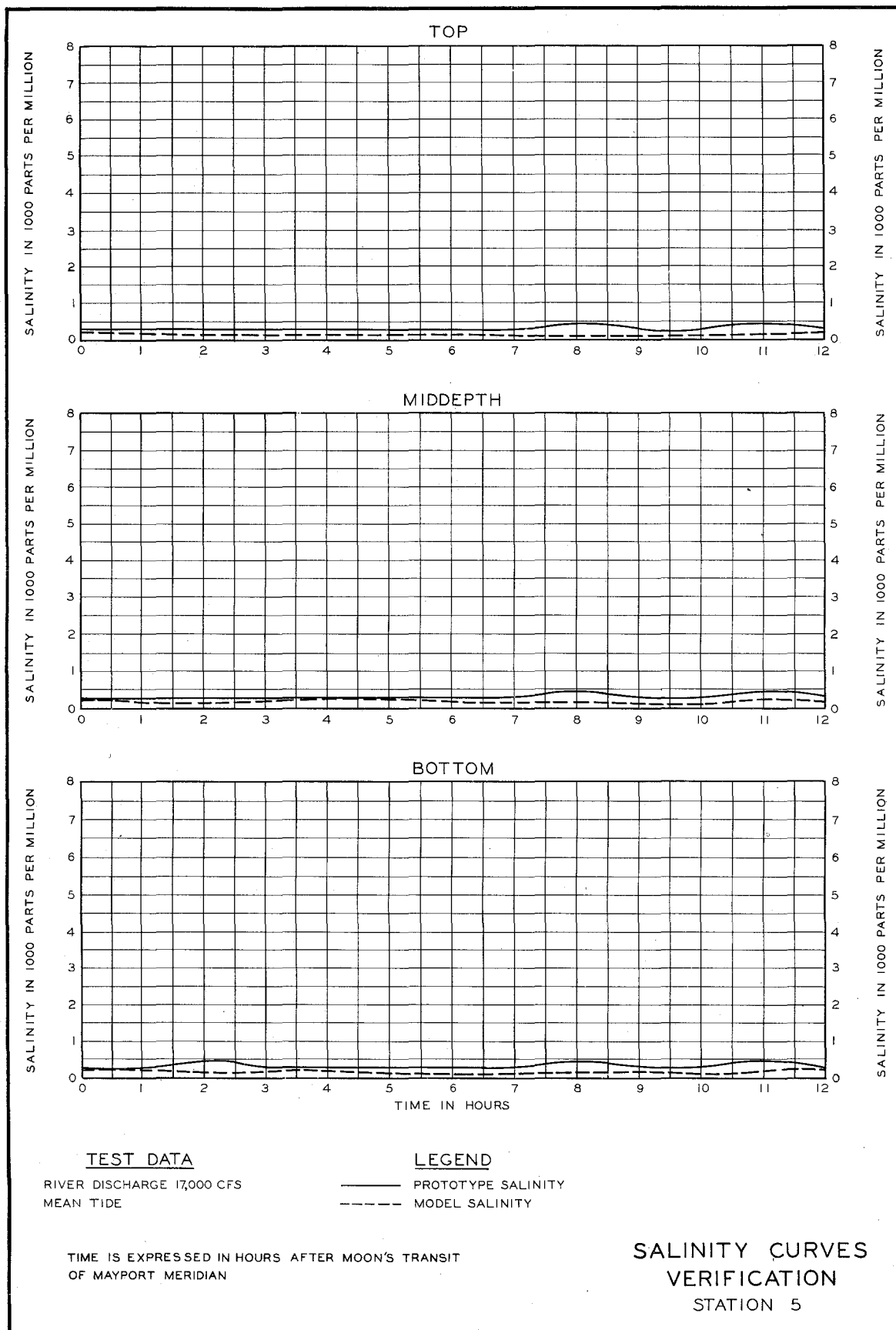
#### LEGEND

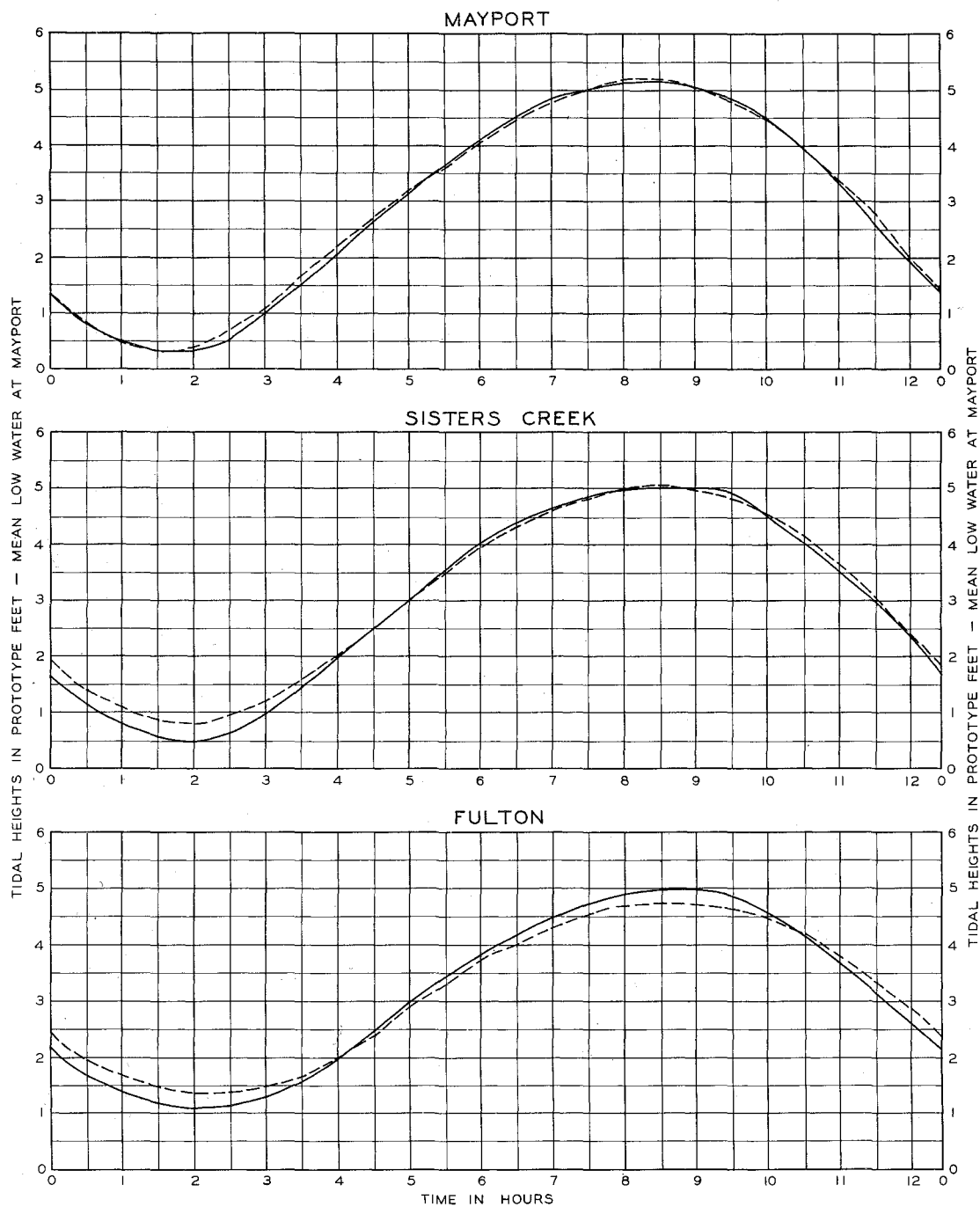
—— PROTOTYPE SALINITY  
- - - - MODEL SALINITY

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

SALINITY CURVES  
VERIFICATION  
STATION 4







#### TEST DATA

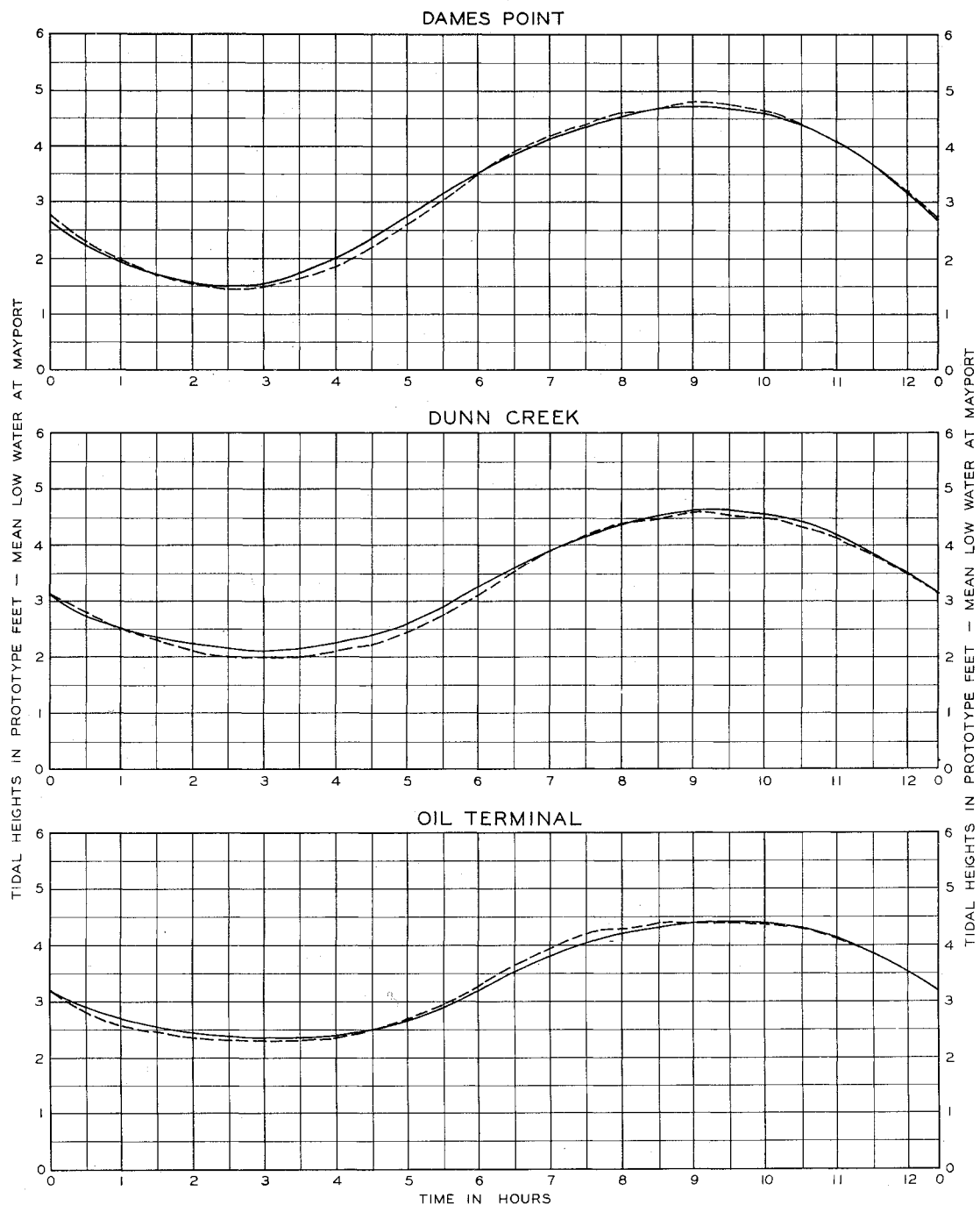
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

TIDAL HEIGHTS  
PLAN A



#### TEST DATA

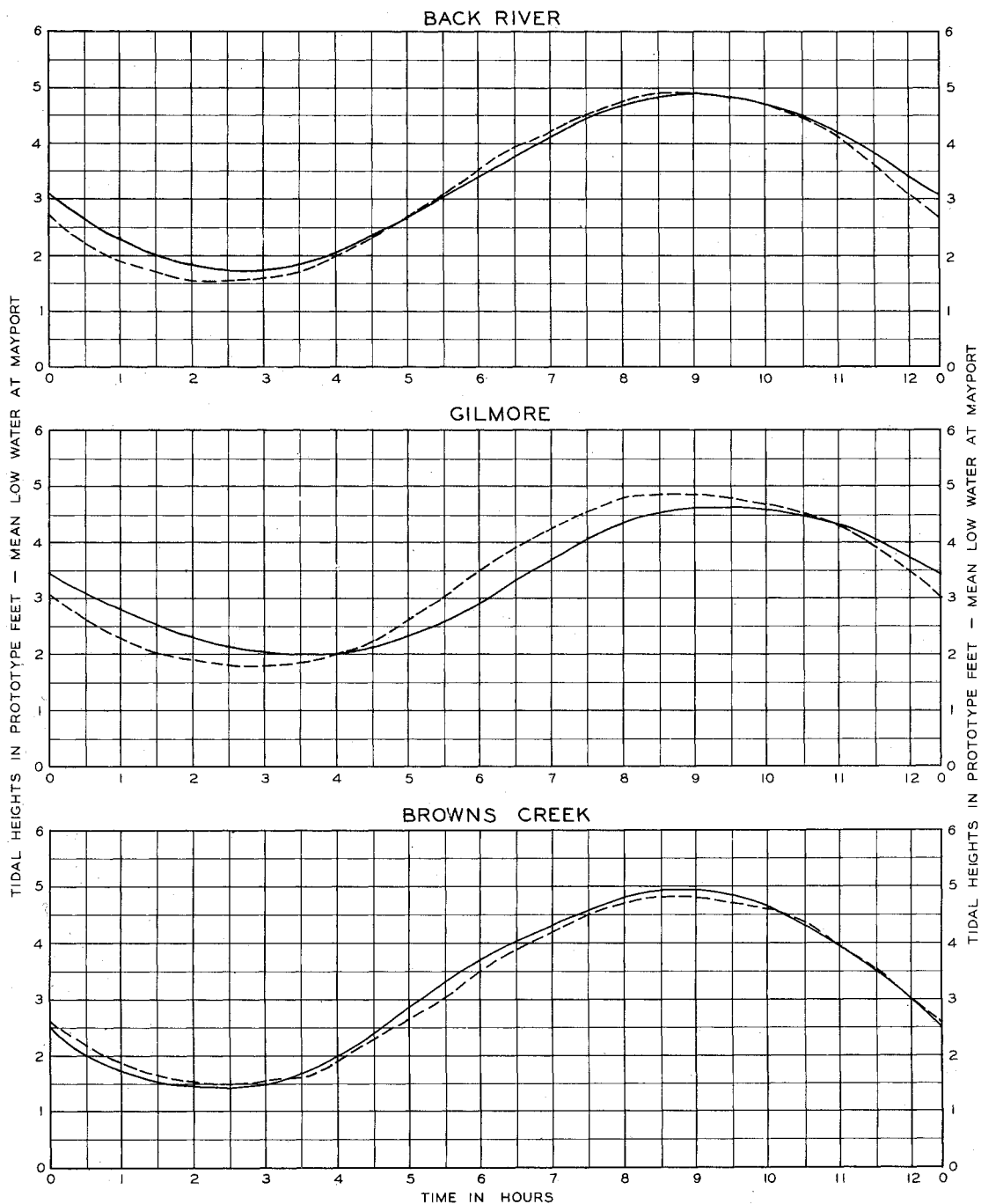
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A



#### TEST DATA

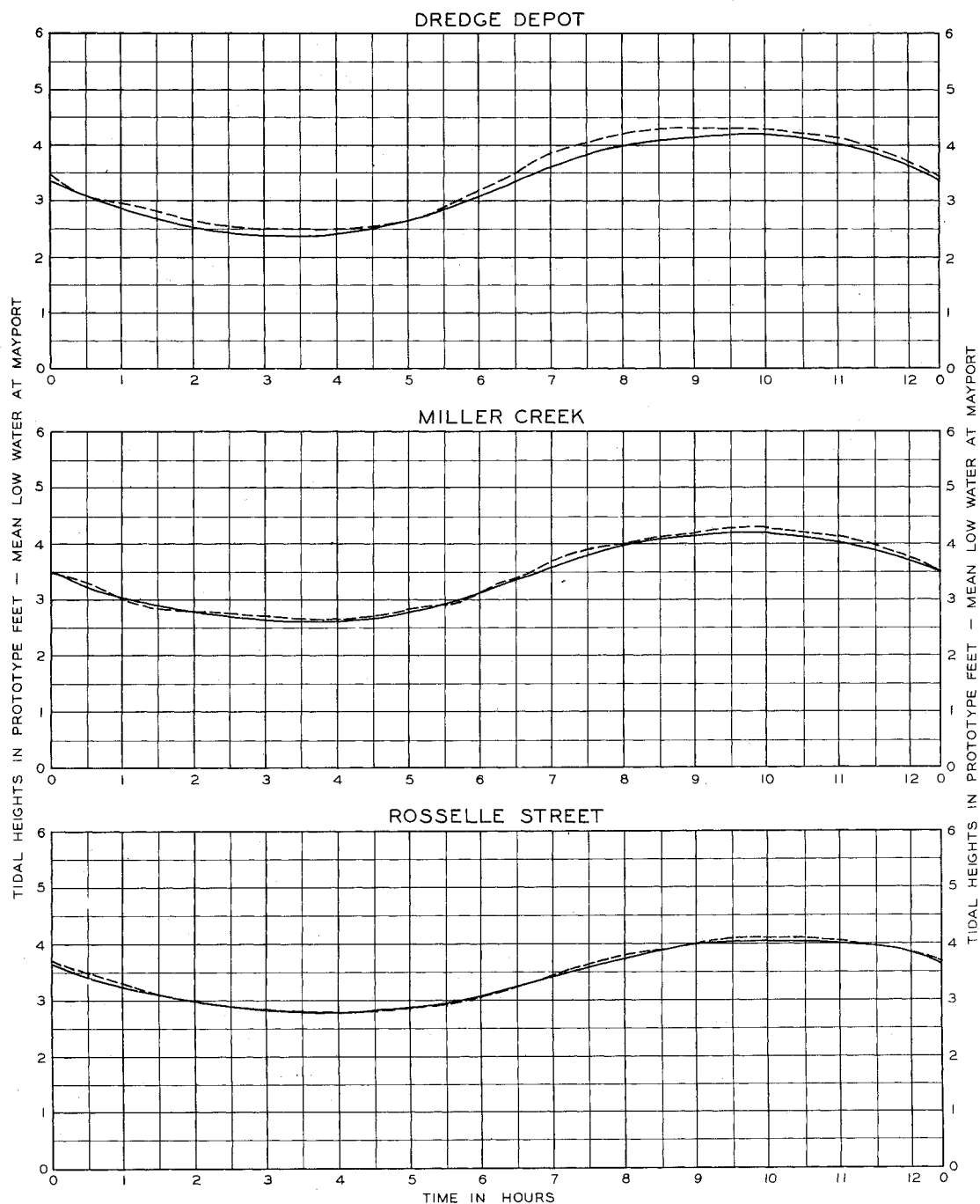
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A



#### TEST DATA

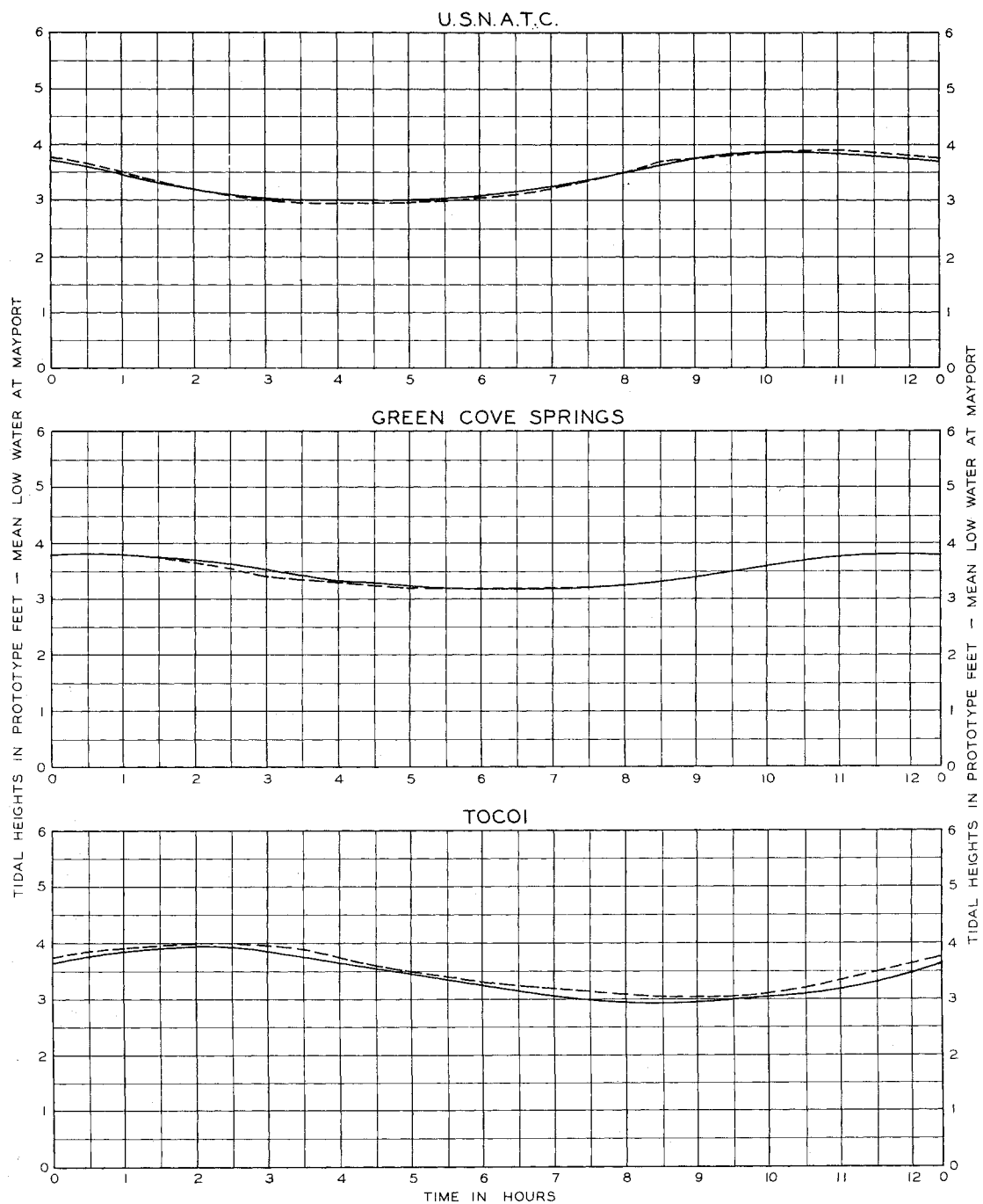
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A



#### TEST DATA

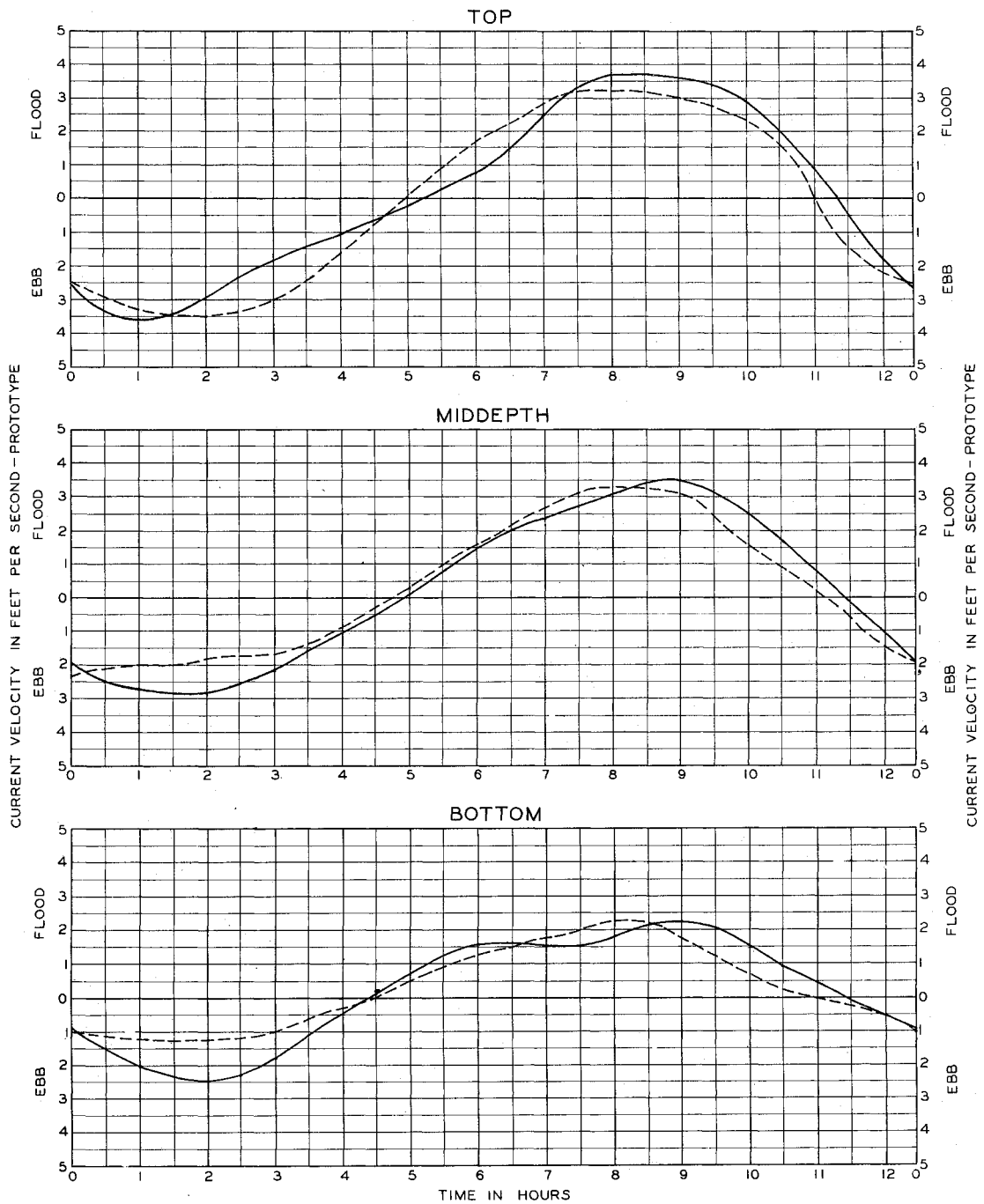
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A



#### TEST DATA

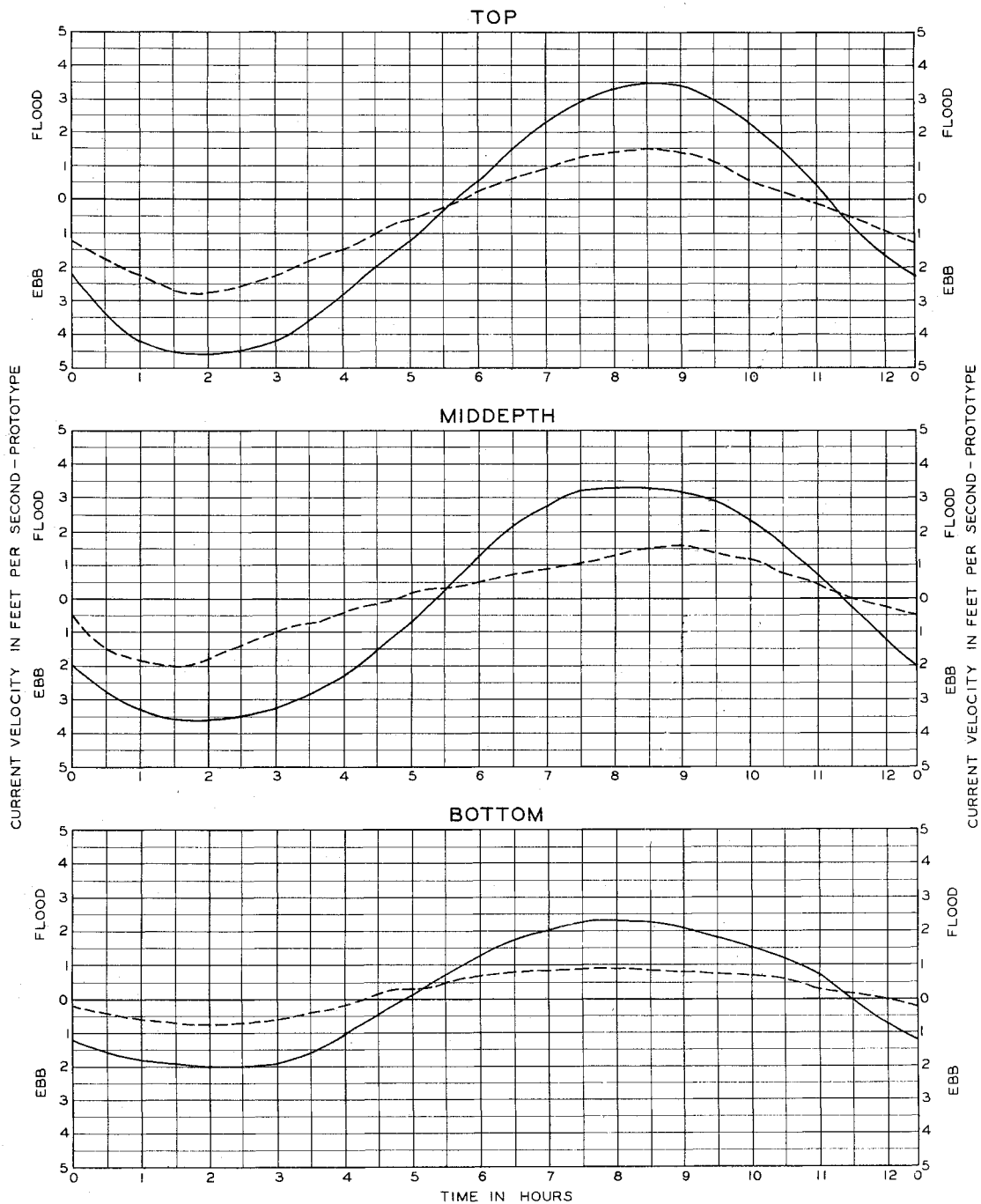
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 2

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

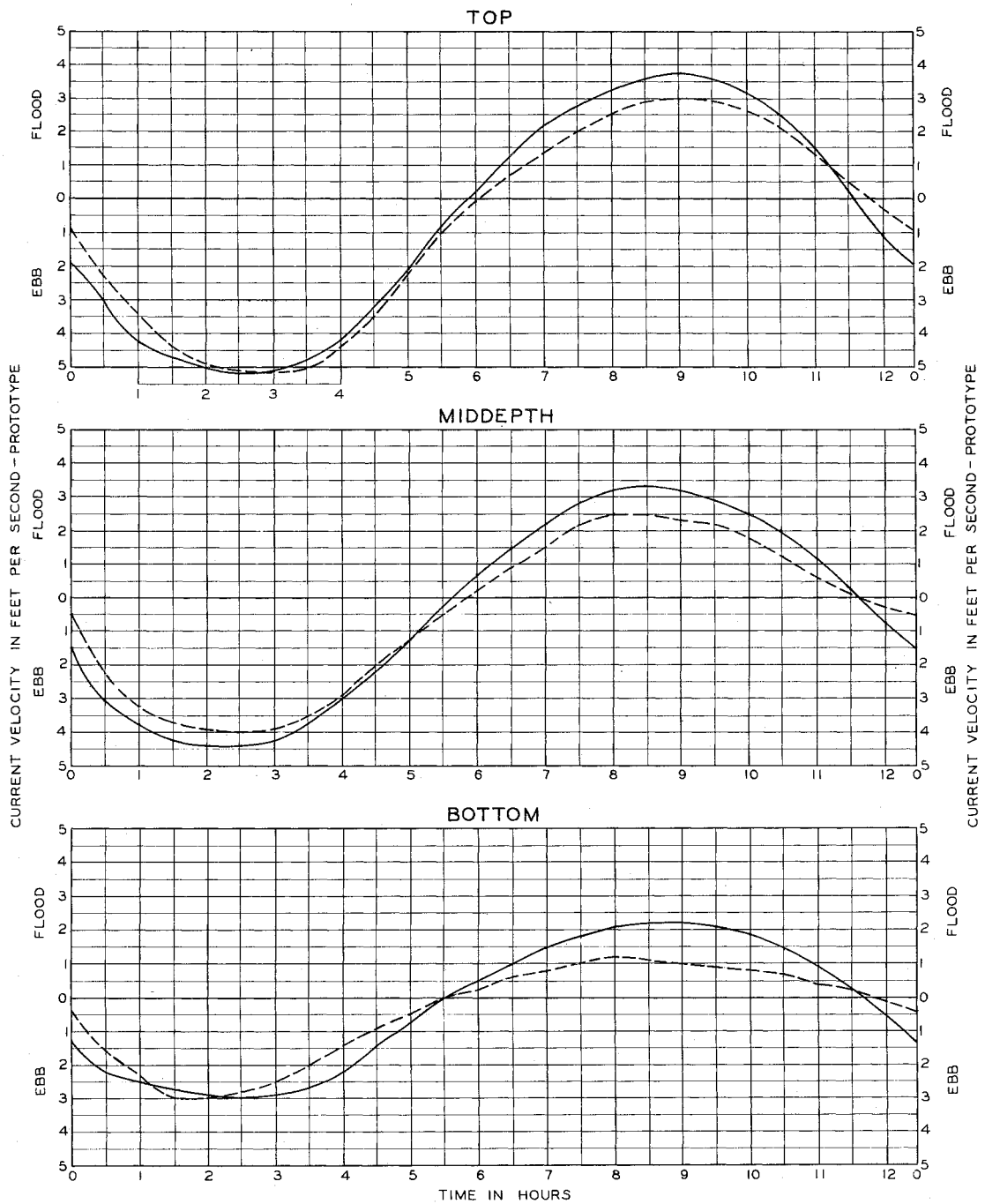
#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 4

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

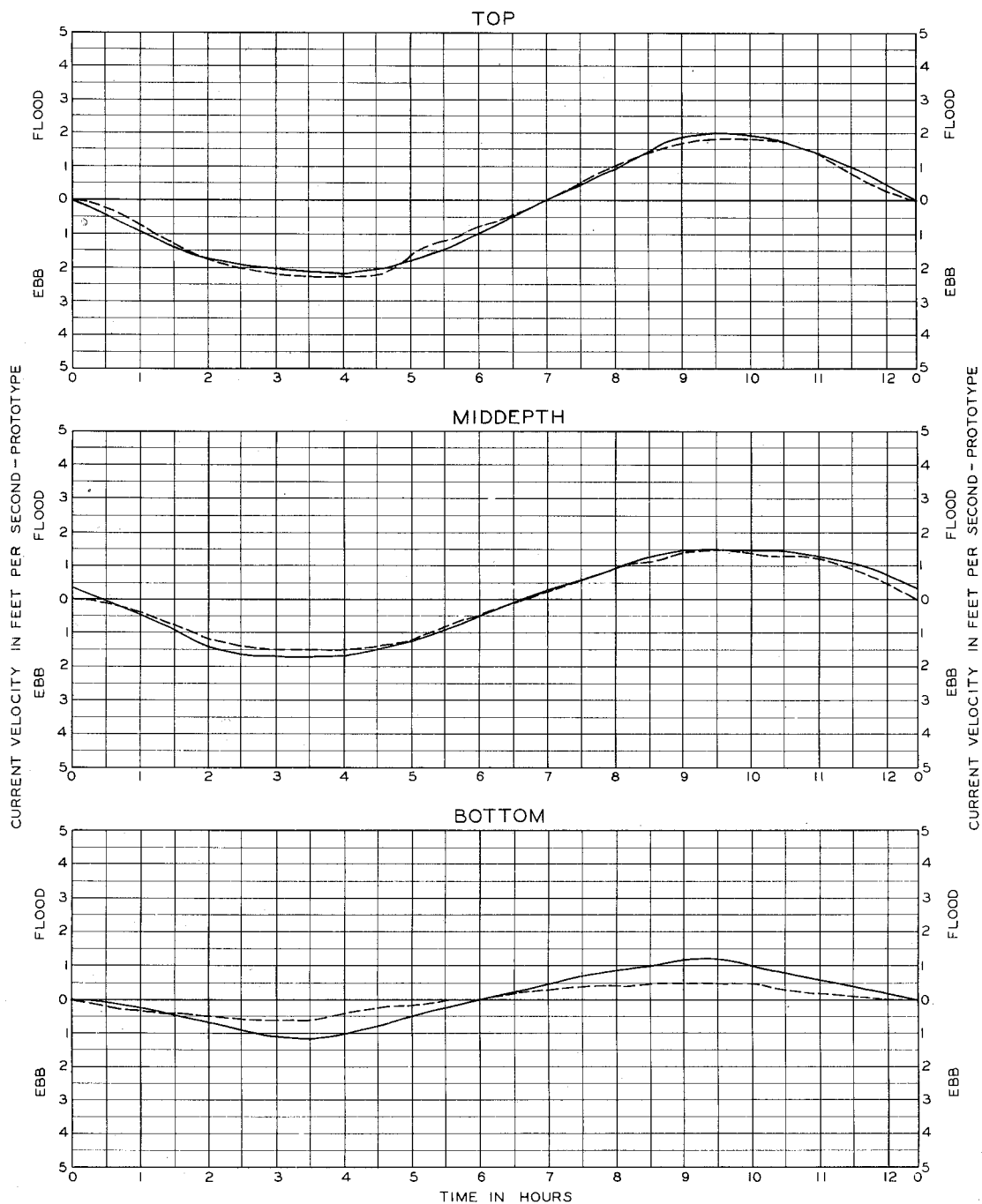
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

—— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 5

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

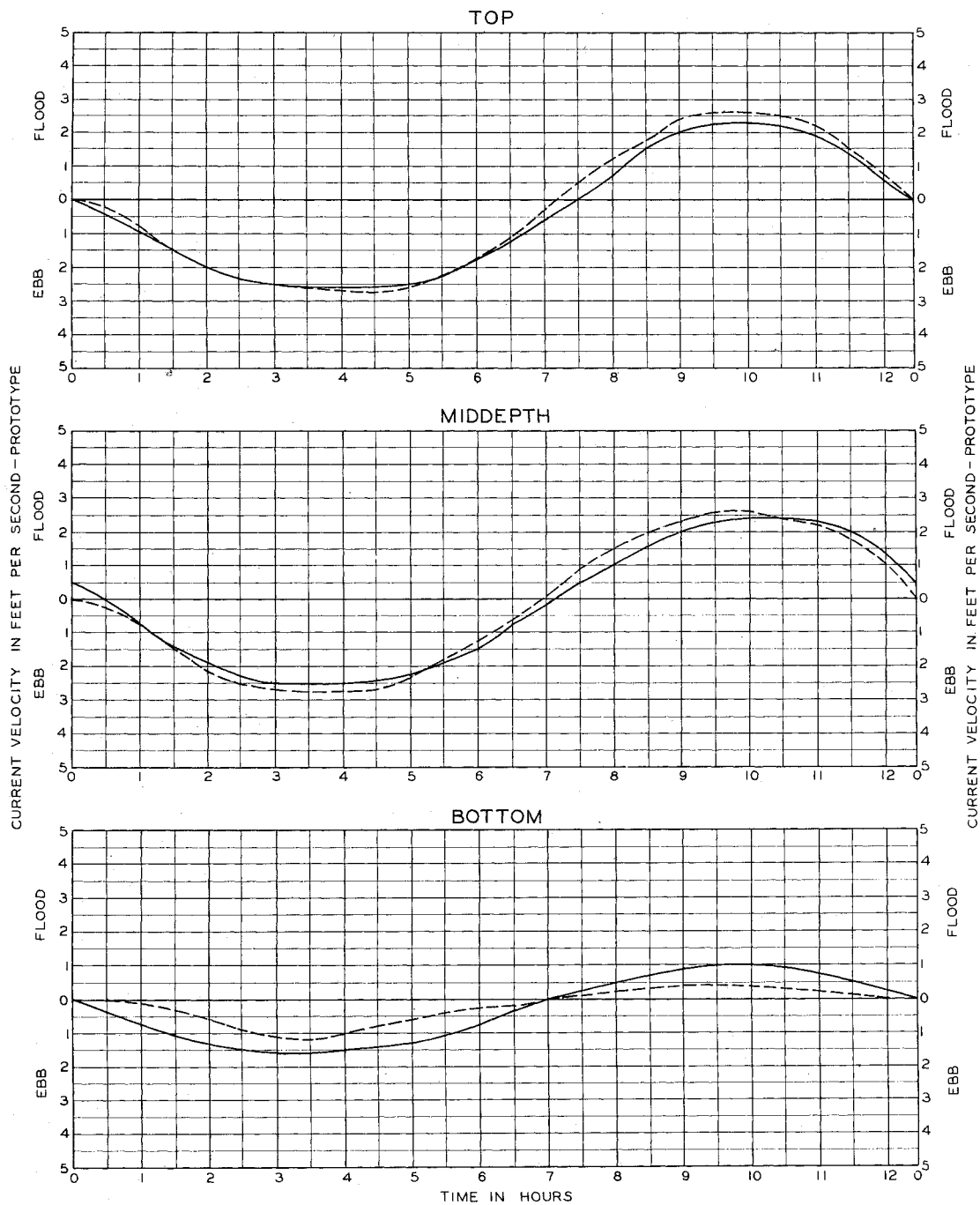
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 6

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

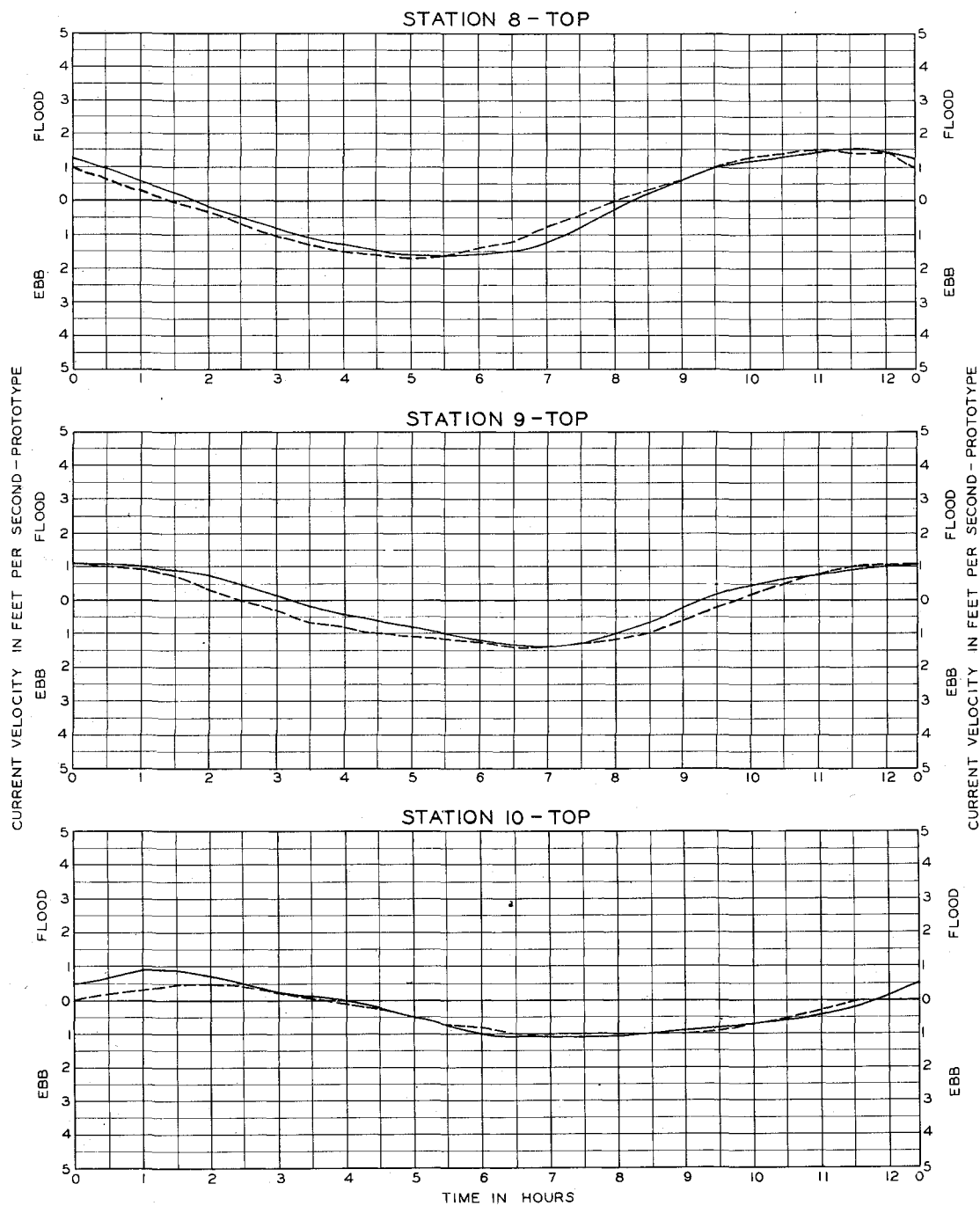
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 7

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

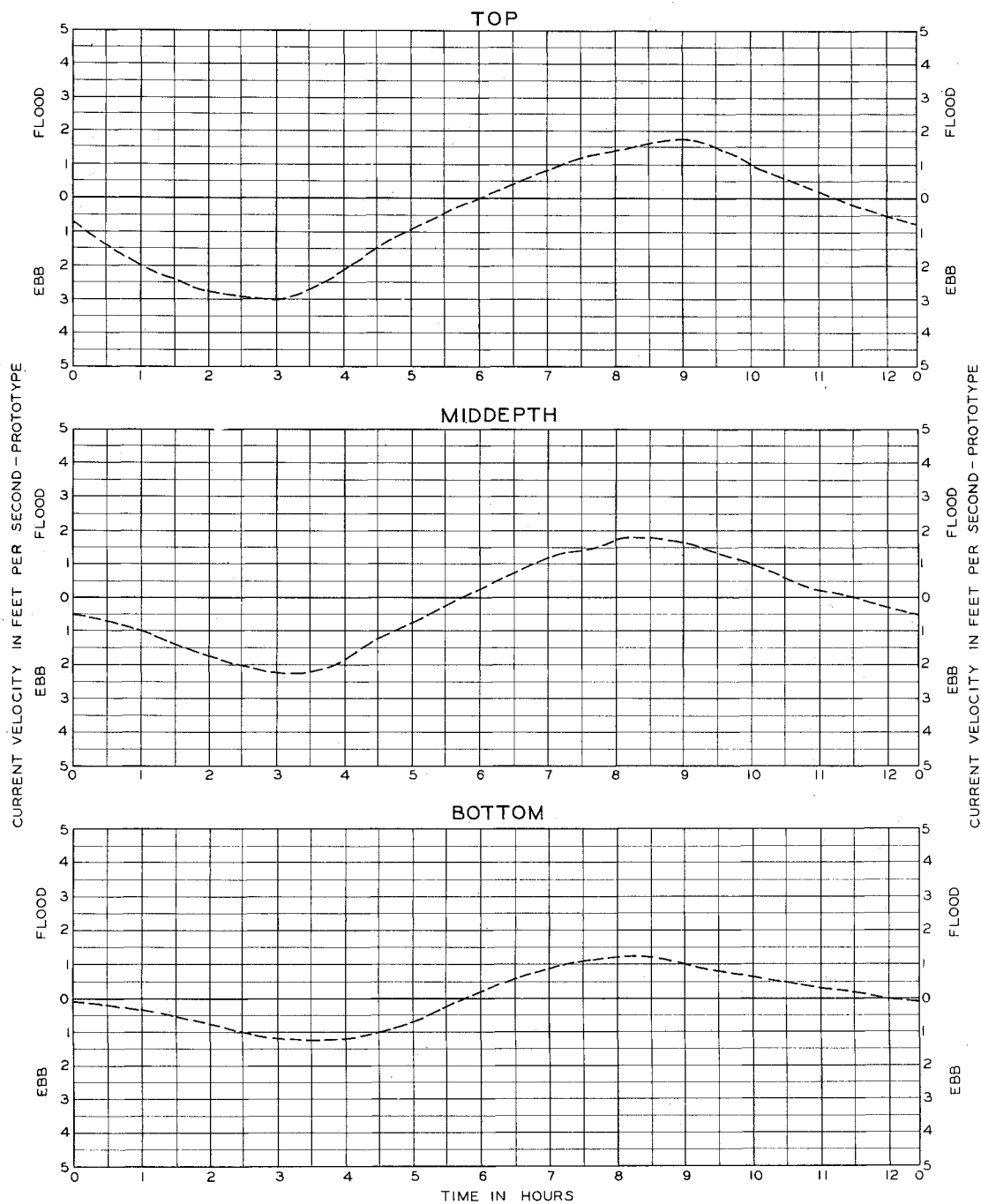
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

### VELOCITY CURVES PLAN A



#### TEST DATA

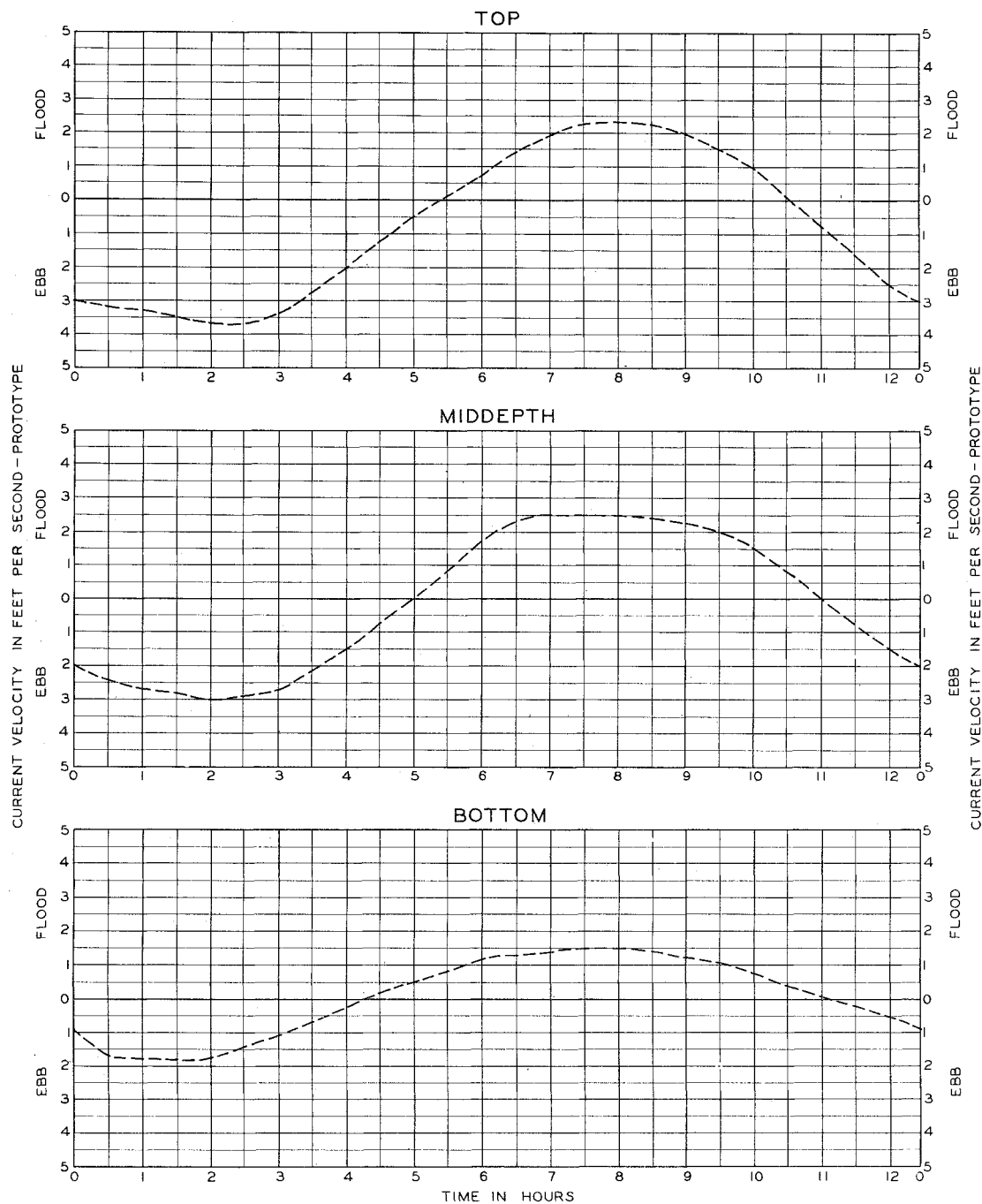
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION II

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

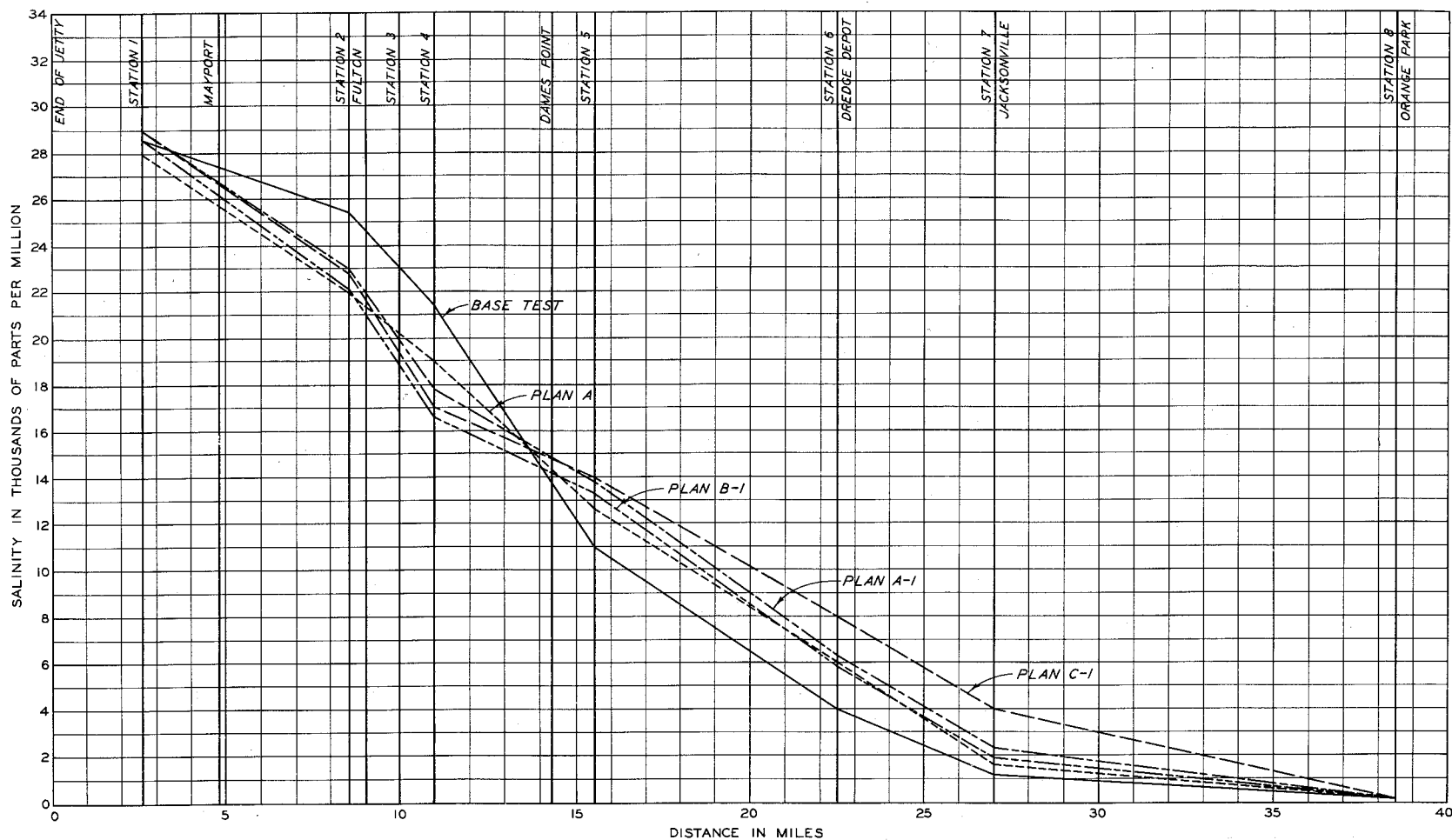
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

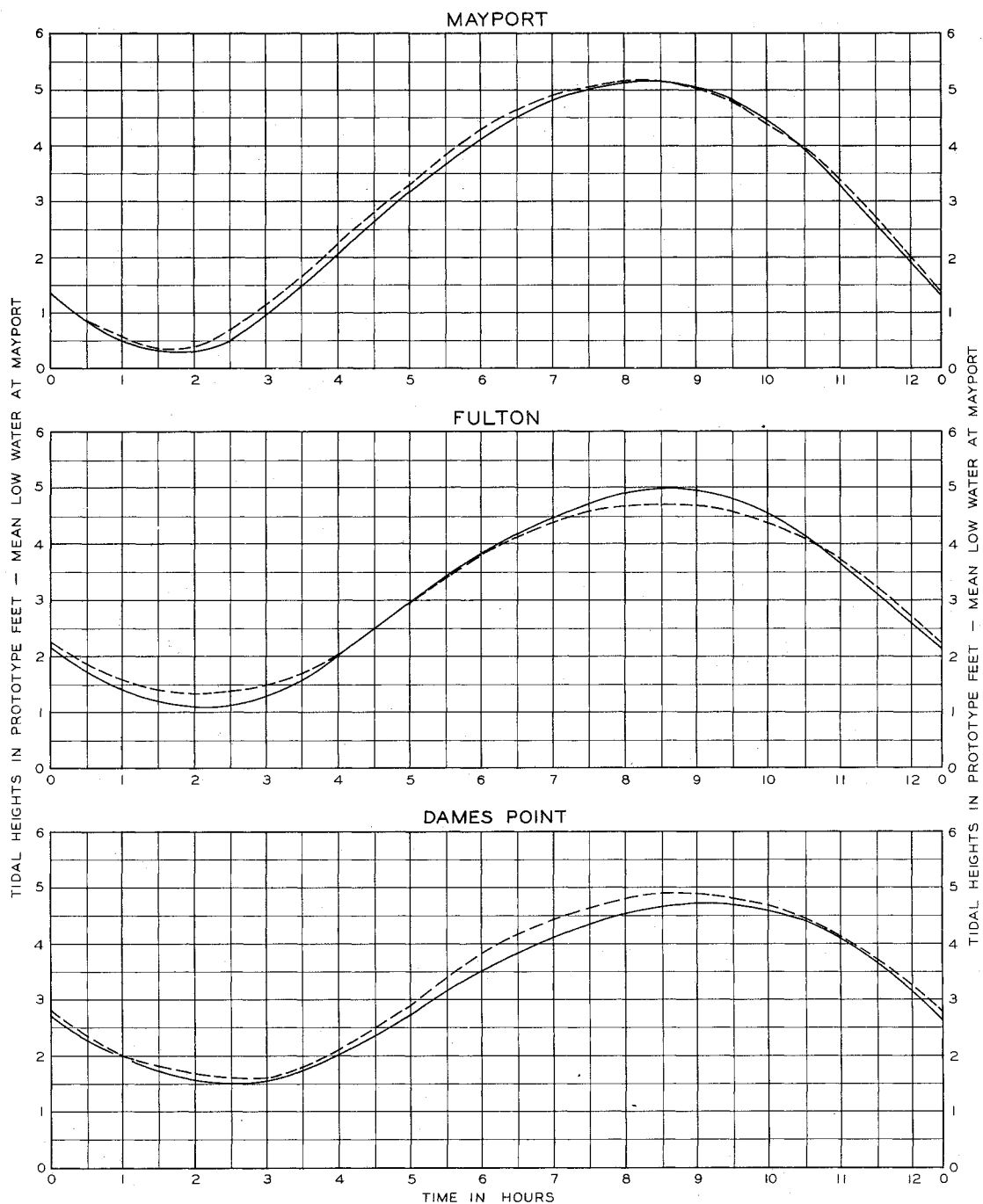


**LEGEND**

- BASE TEST
- PLAN A
- ..... PLAN A-1
- . - . - PLAN B-1
- PLAN C-1

NOTE: VALUES SHOWN REPRESENT MAXIMUM SALINITY RECORDED AT EACH SAMPLING STATION FOR EACH BASIC CUTOFF ALIGNMENT TESTED

**PROFILE OF  
MAXIMUM SALINITY**



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

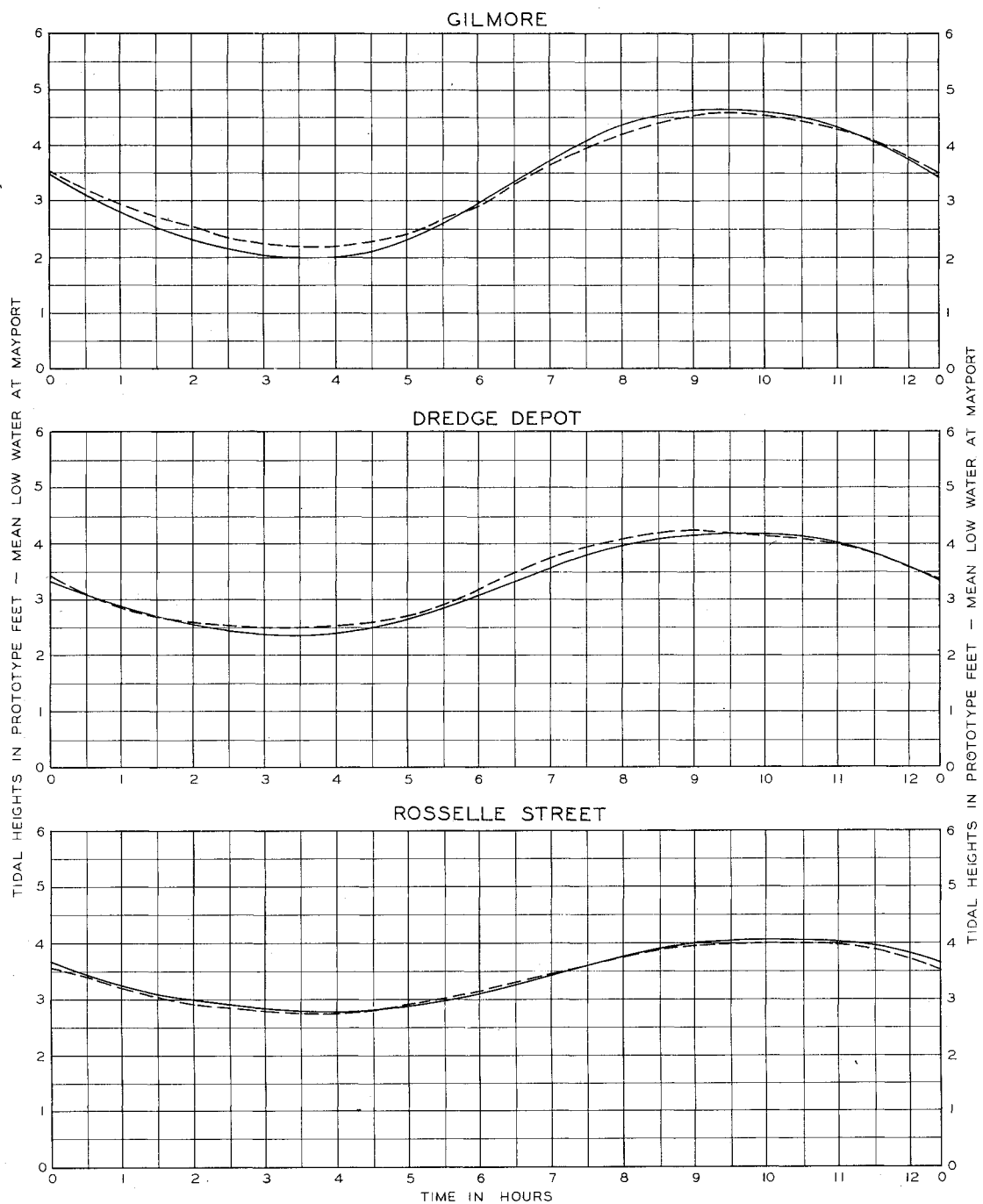
#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-1





#### TEST DATA

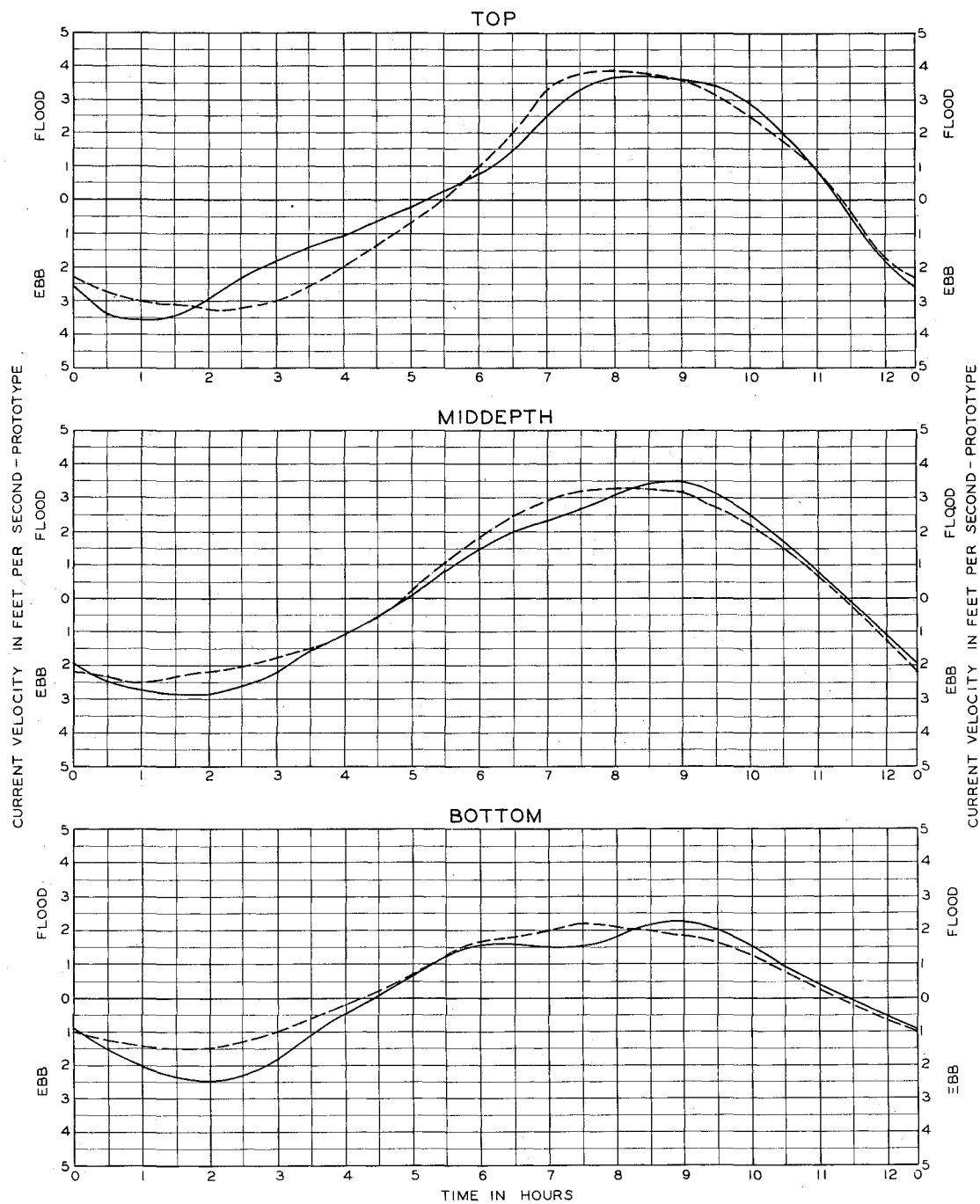
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-1



#### TEST DATA

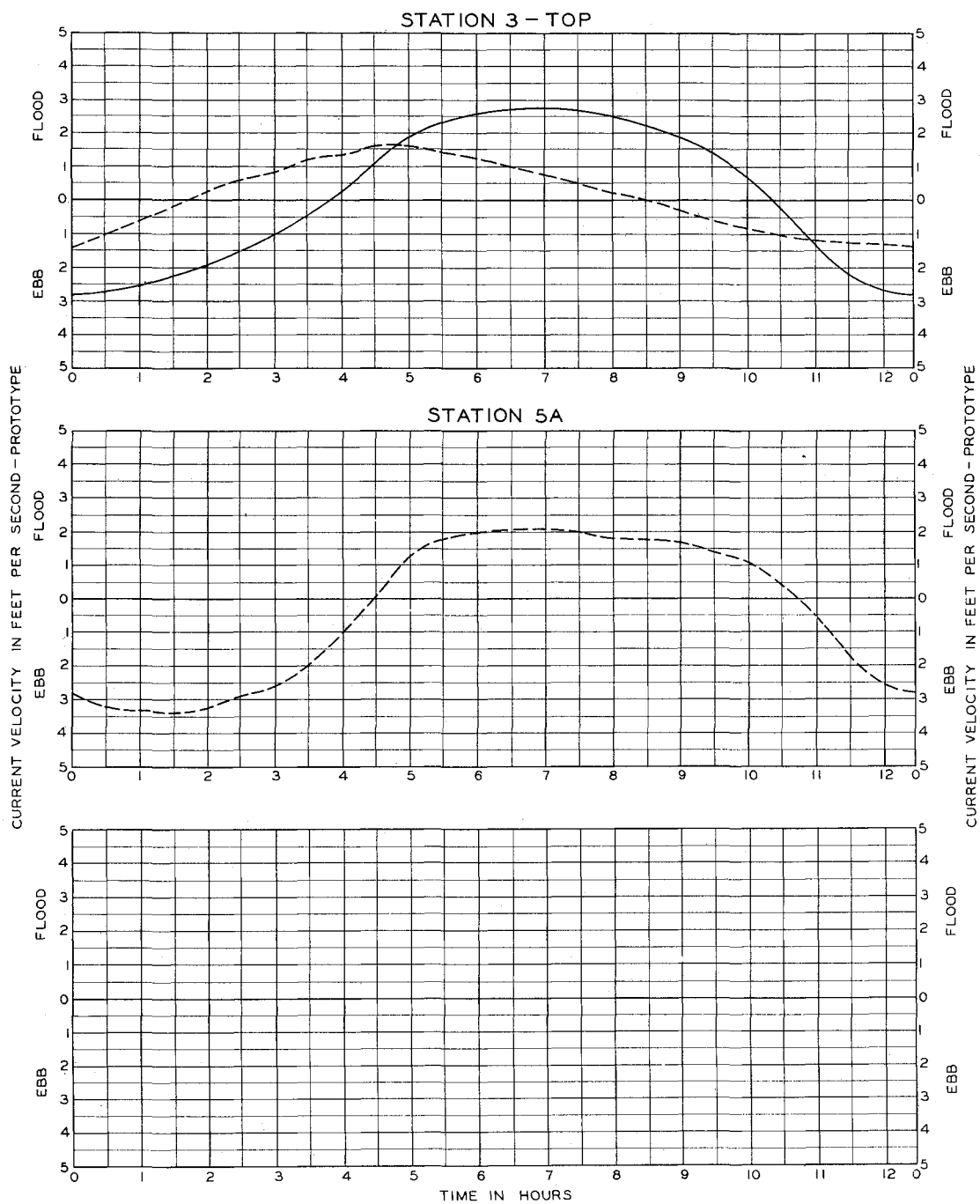
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-1 STATION 2

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

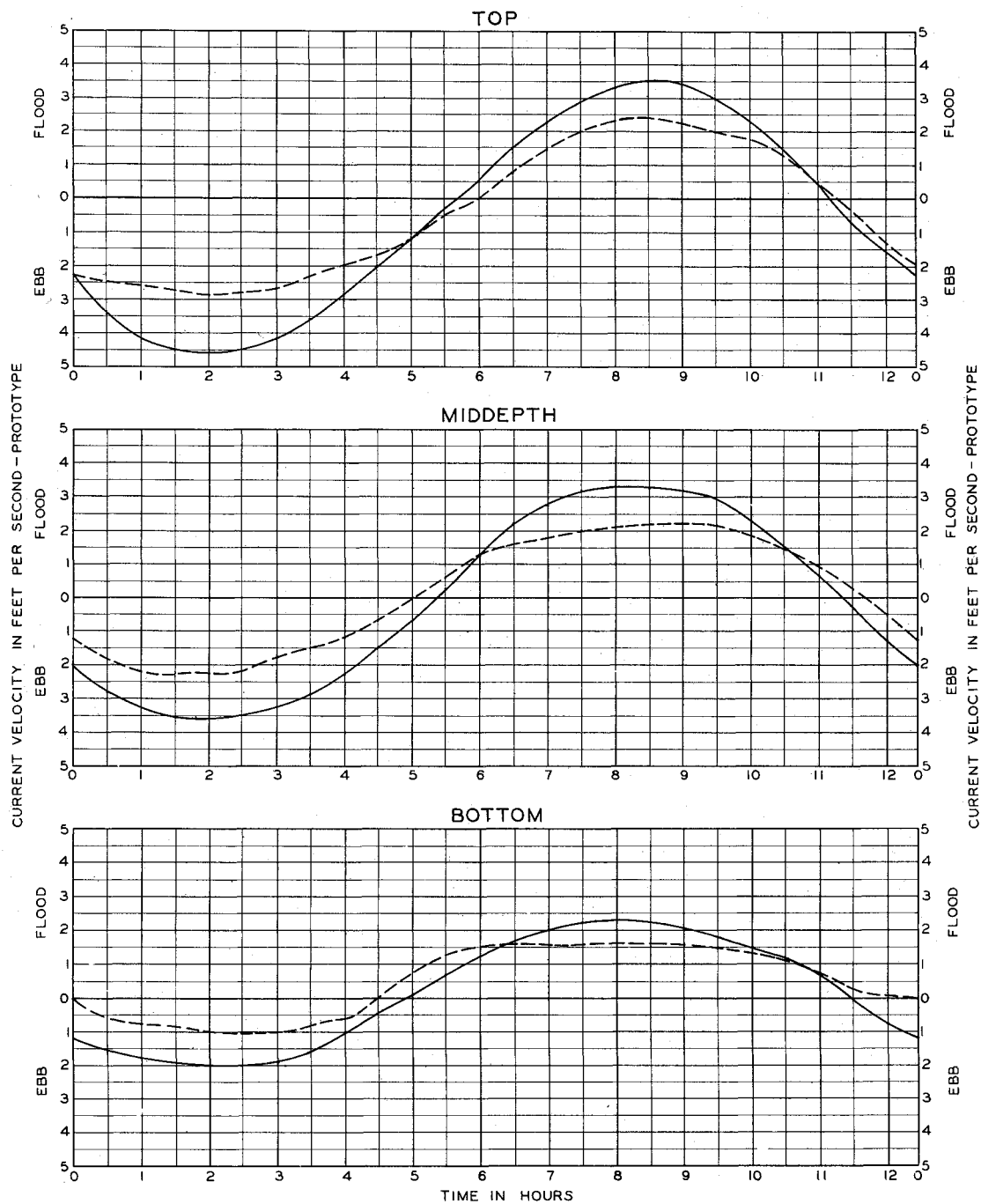
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

VELOCITY CURVES  
PLAN A-1



**TEST DATA**

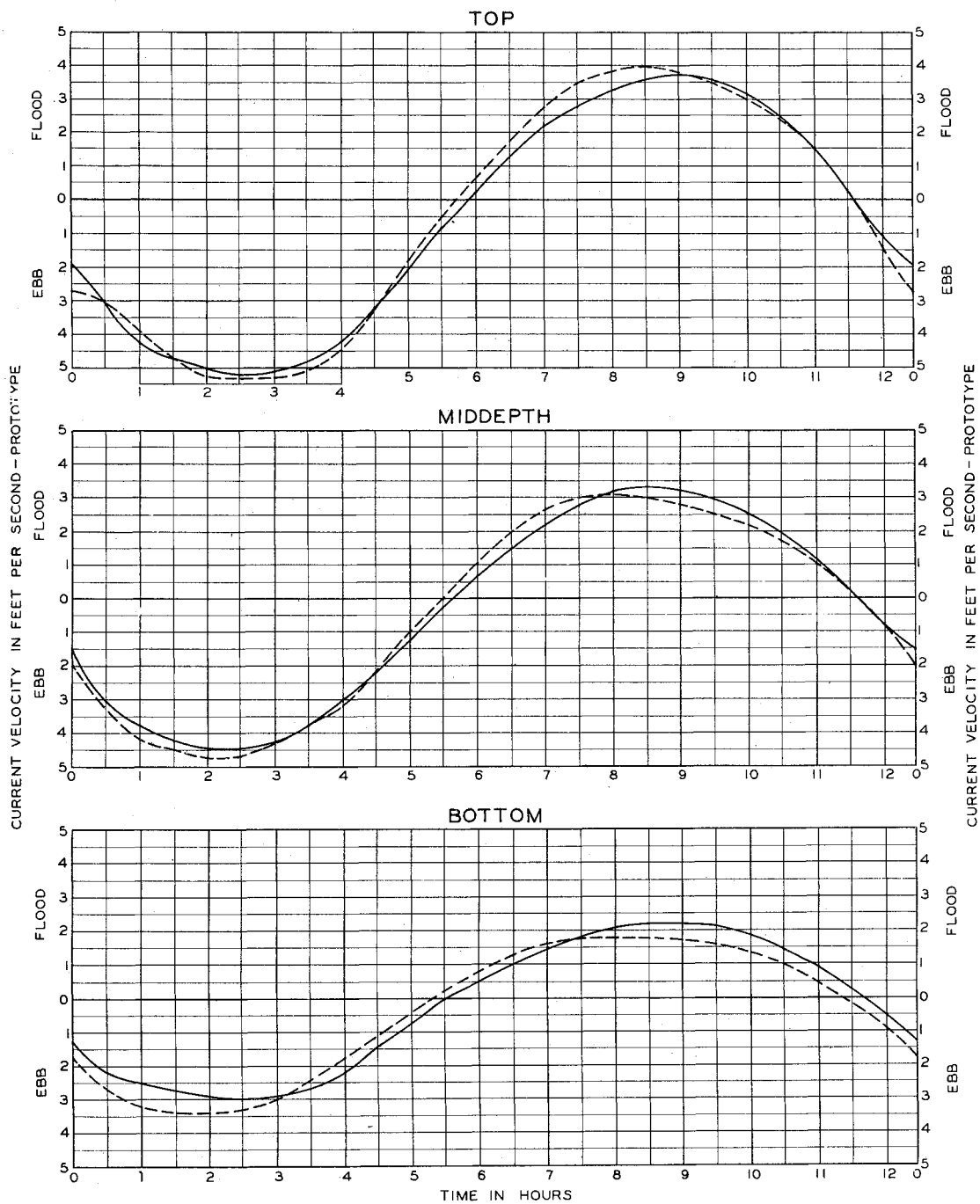
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

**LEGEND**

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

**VELOCITY CURVES  
PLAN A-1  
STATION 4**

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

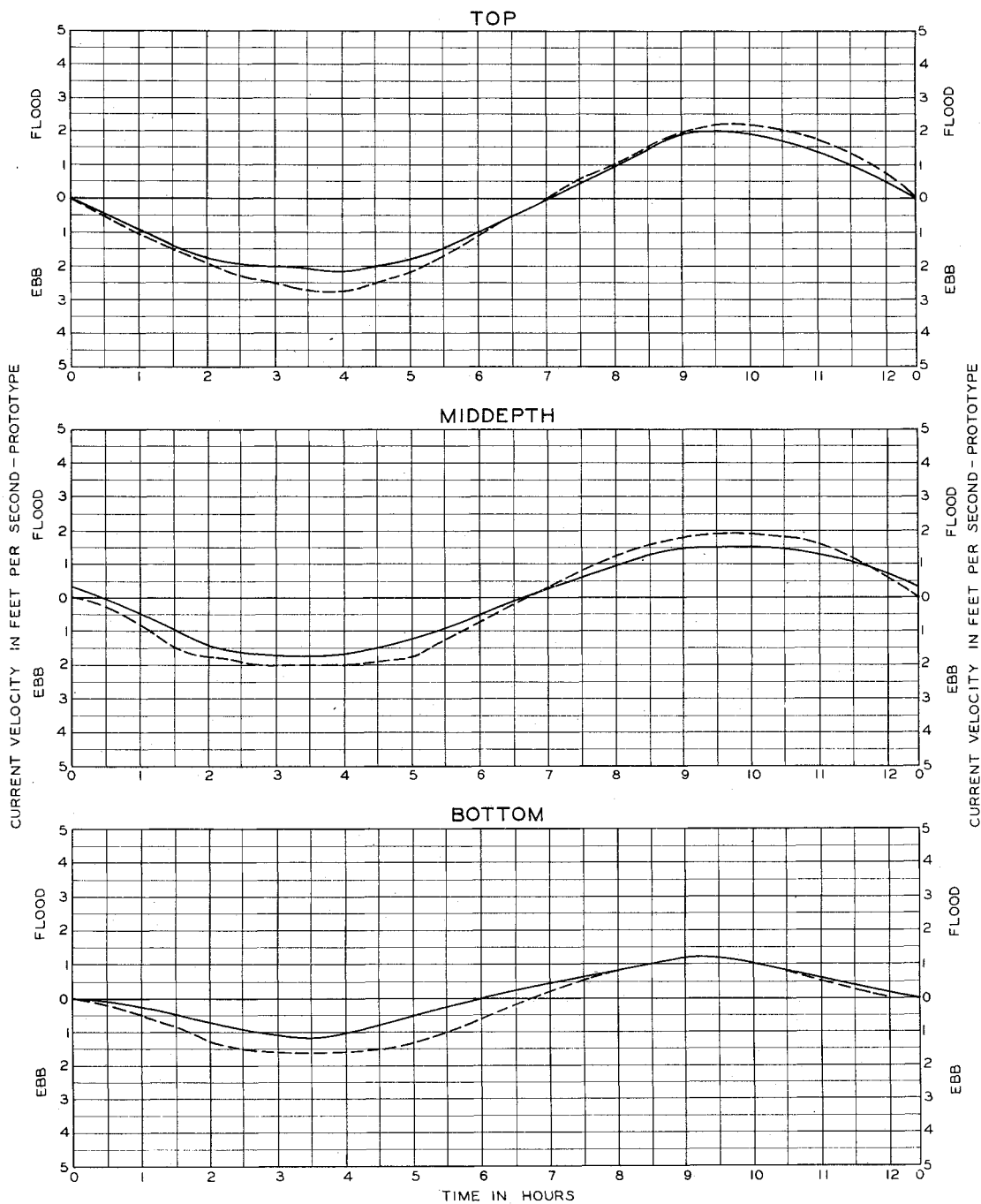
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

**VELOCITY CURVES  
PLAN A-1  
STATION 5**



#### TEST DATA

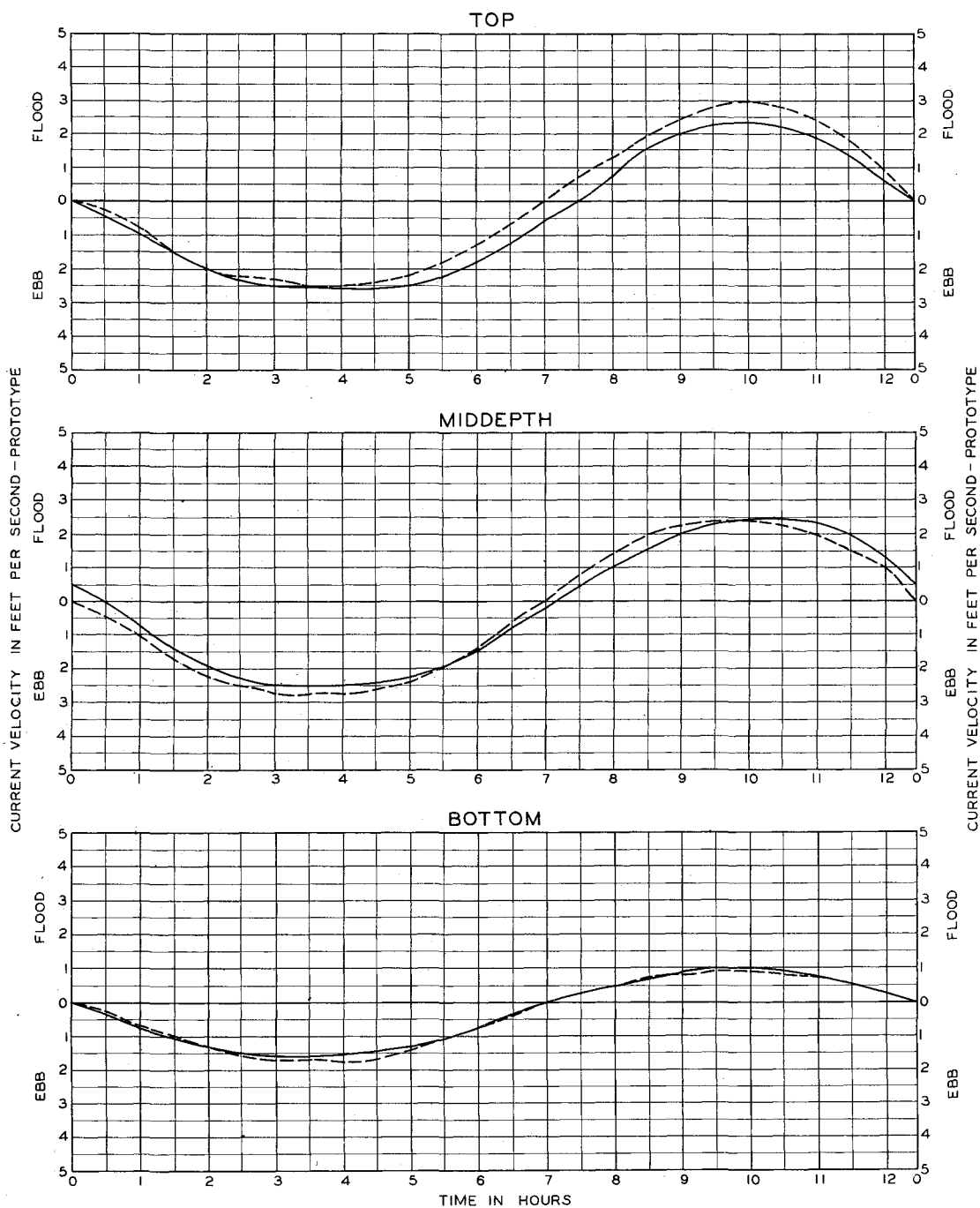
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

VELOCITY CURVES  
PLAN A-1  
STATION 6



### TEST DATA

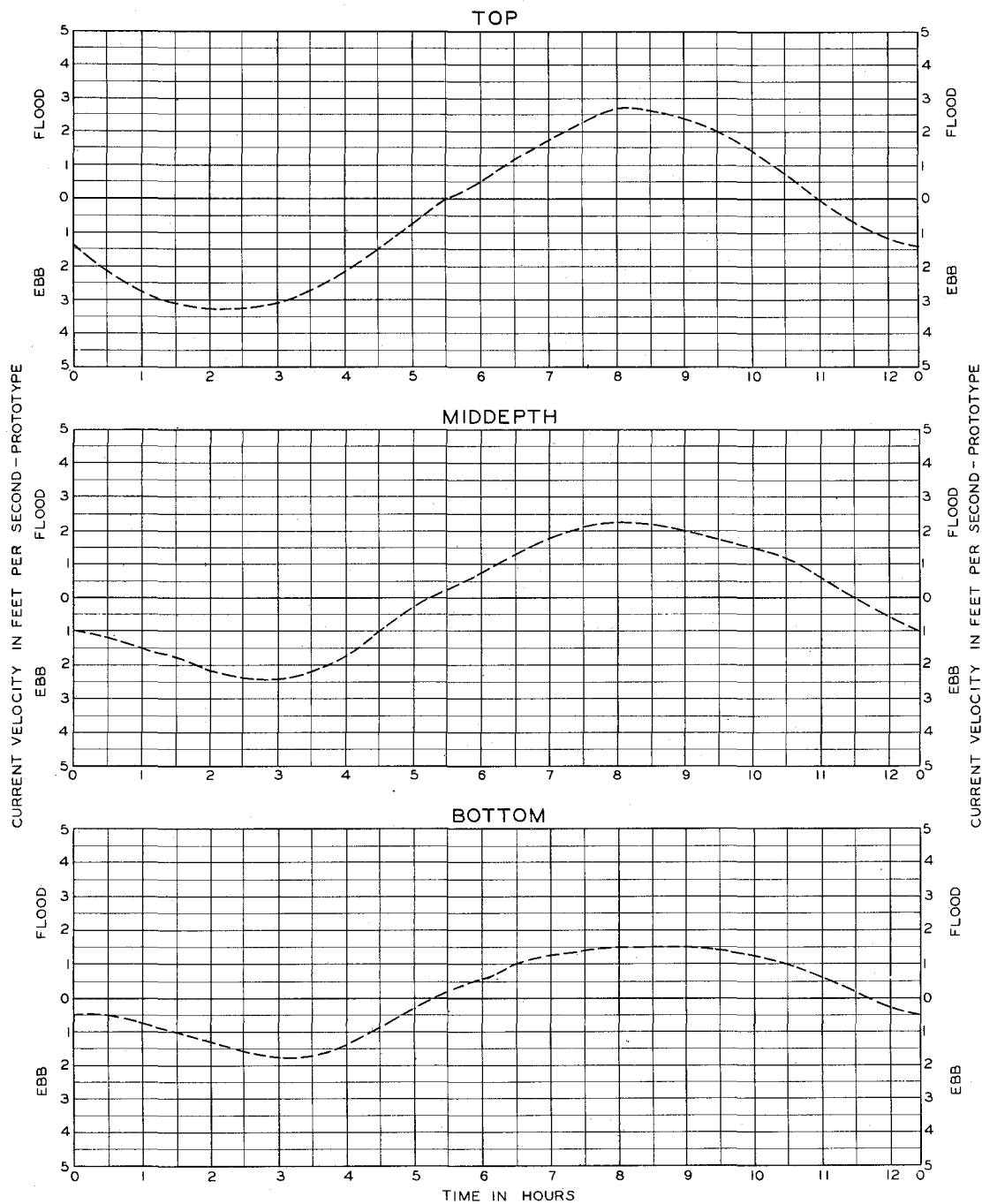
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

## VELOCITY CURVES PLAN A-1 STATION 7

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



**TEST DATA**

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

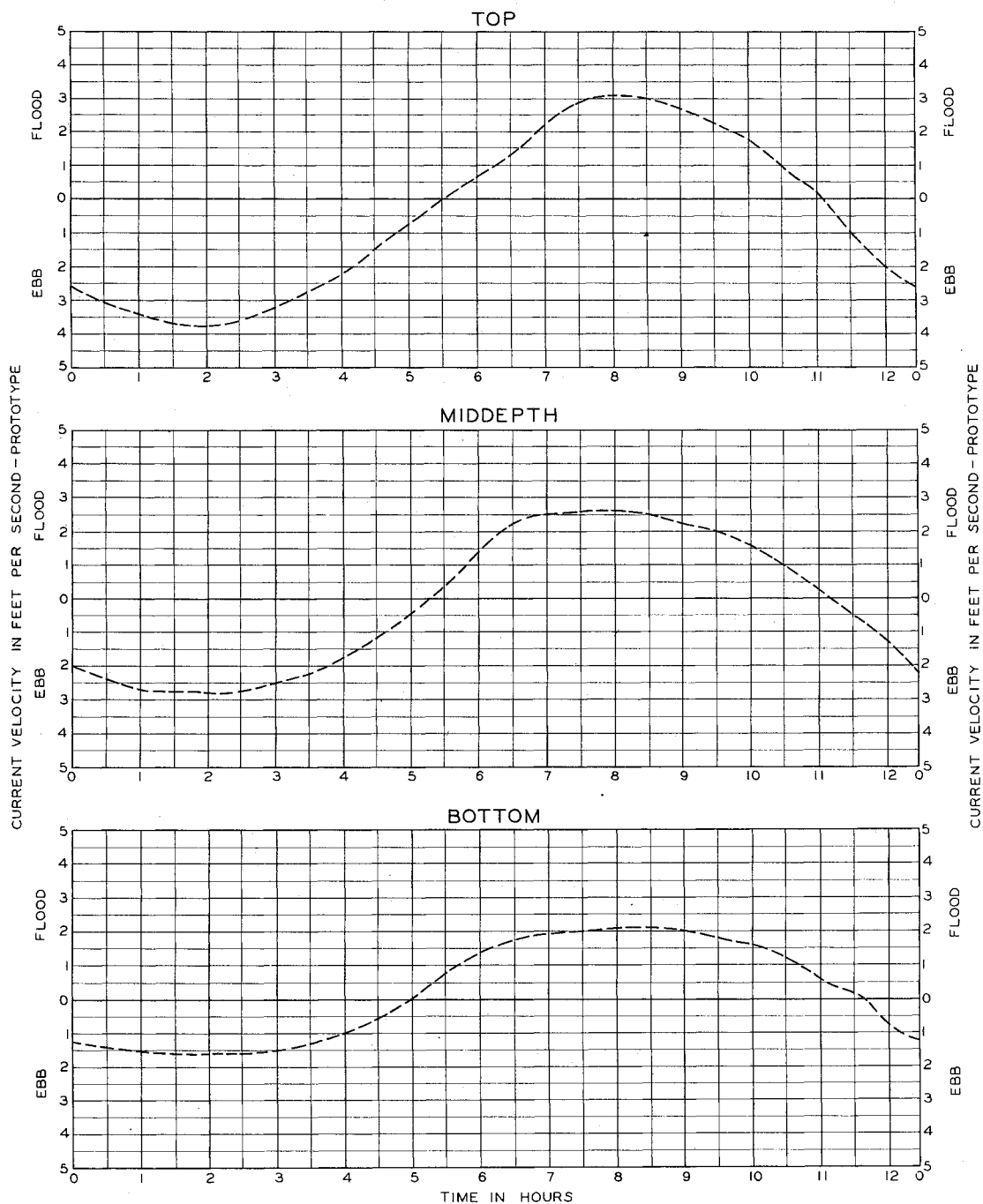
**LEGEND**

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

**VELOCITY CURVES  
PLAN A-I  
STATION II**

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

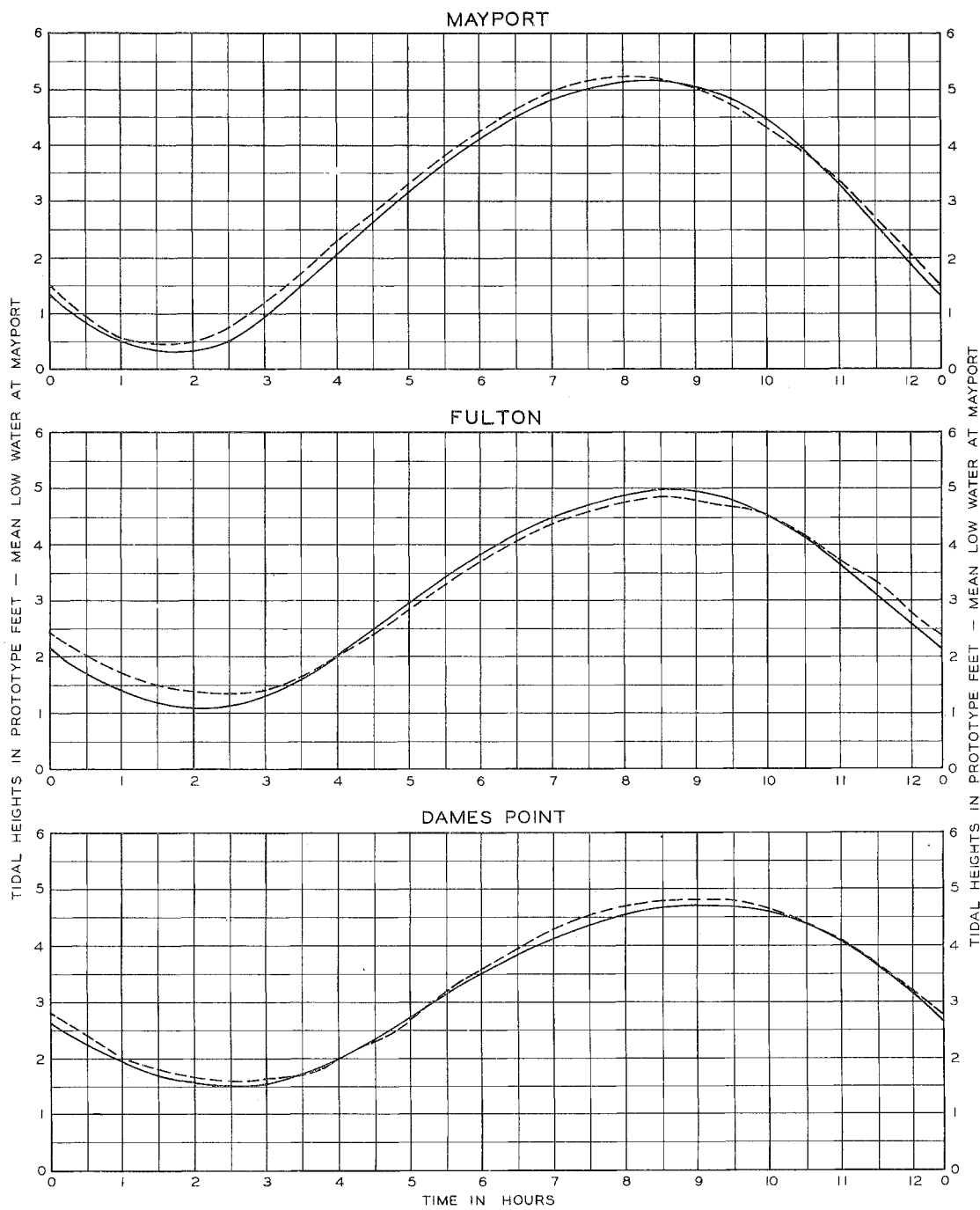
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-1 STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

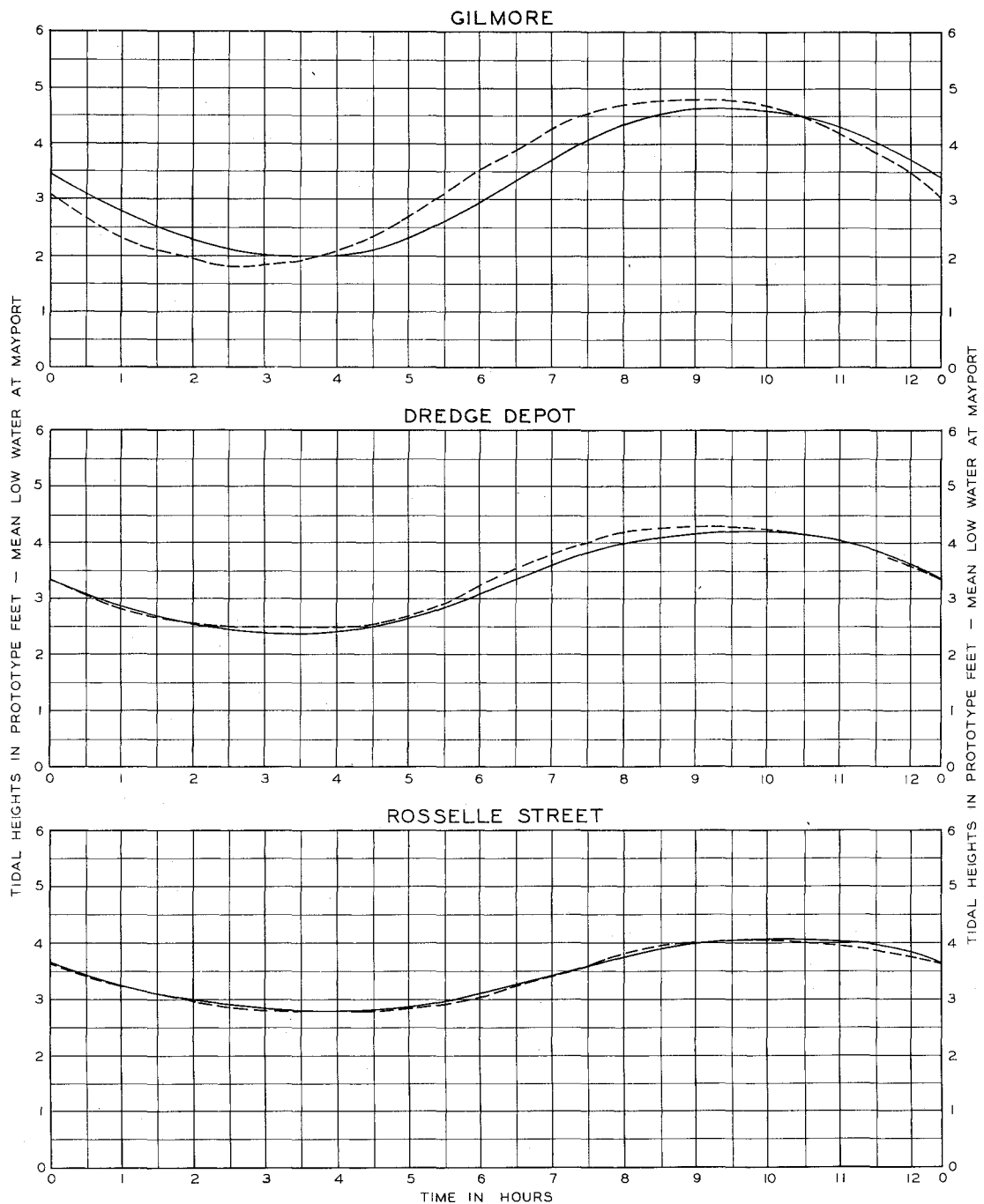
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-2



#### TEST DATA

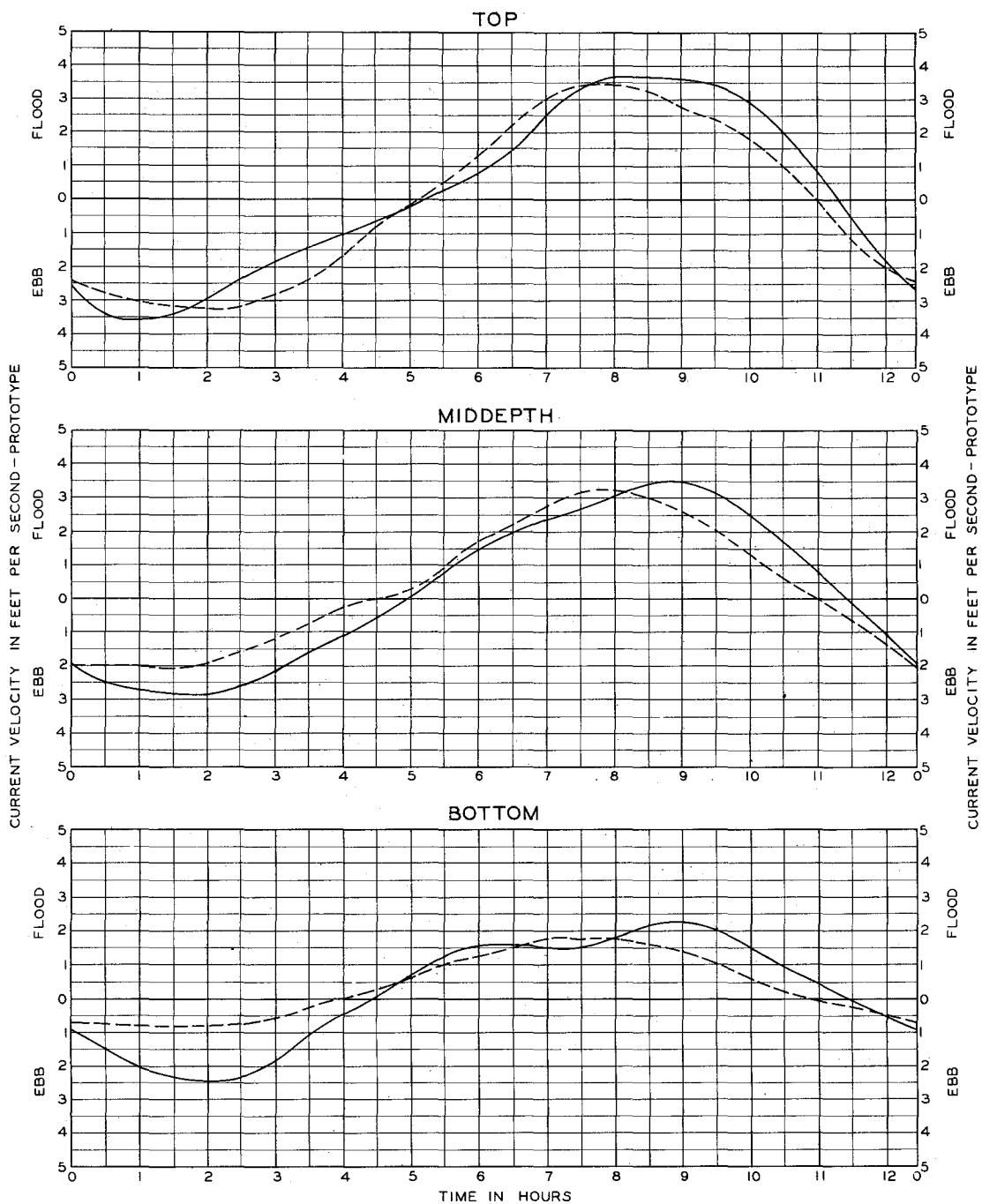
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-2



#### TEST DATA

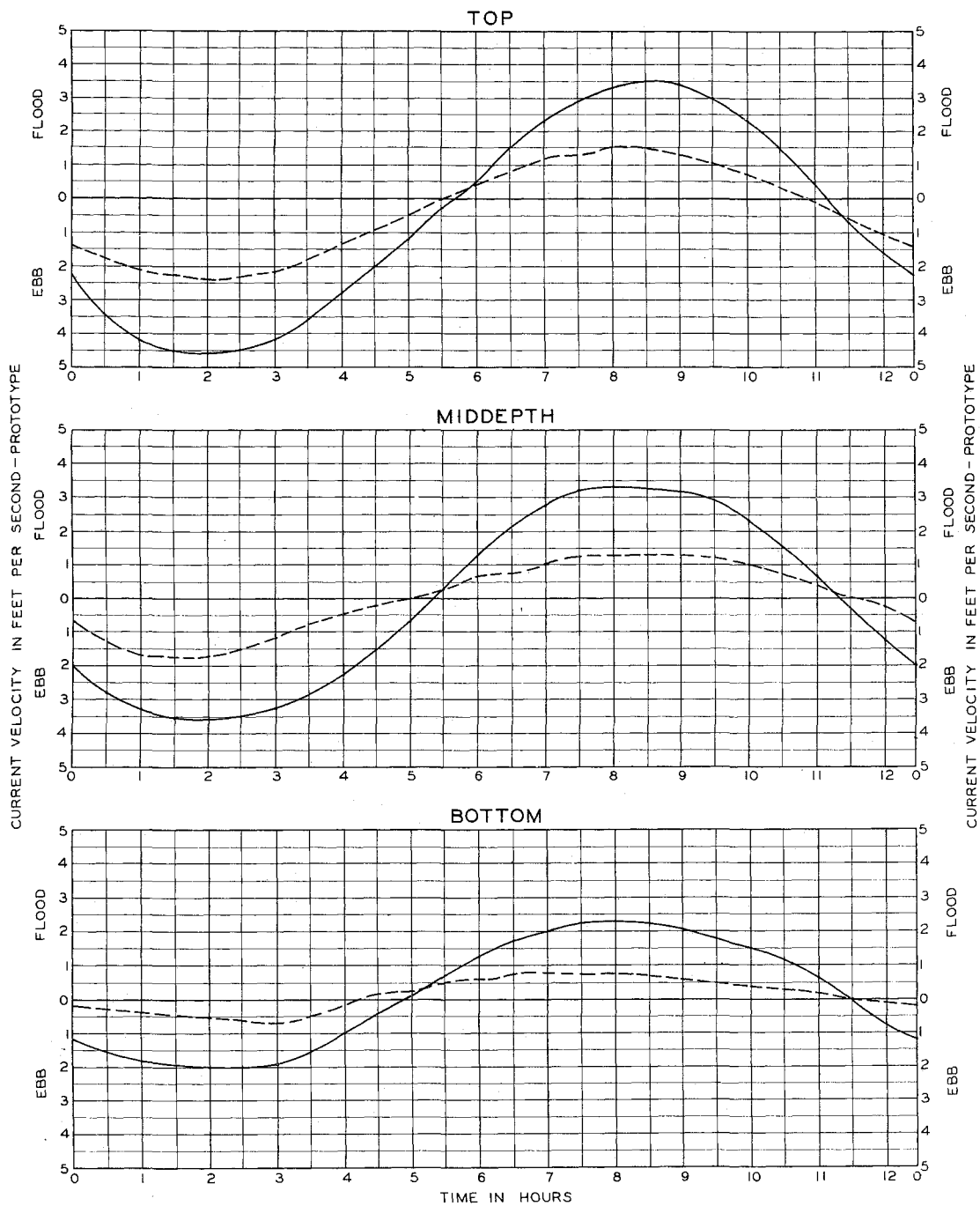
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 2

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

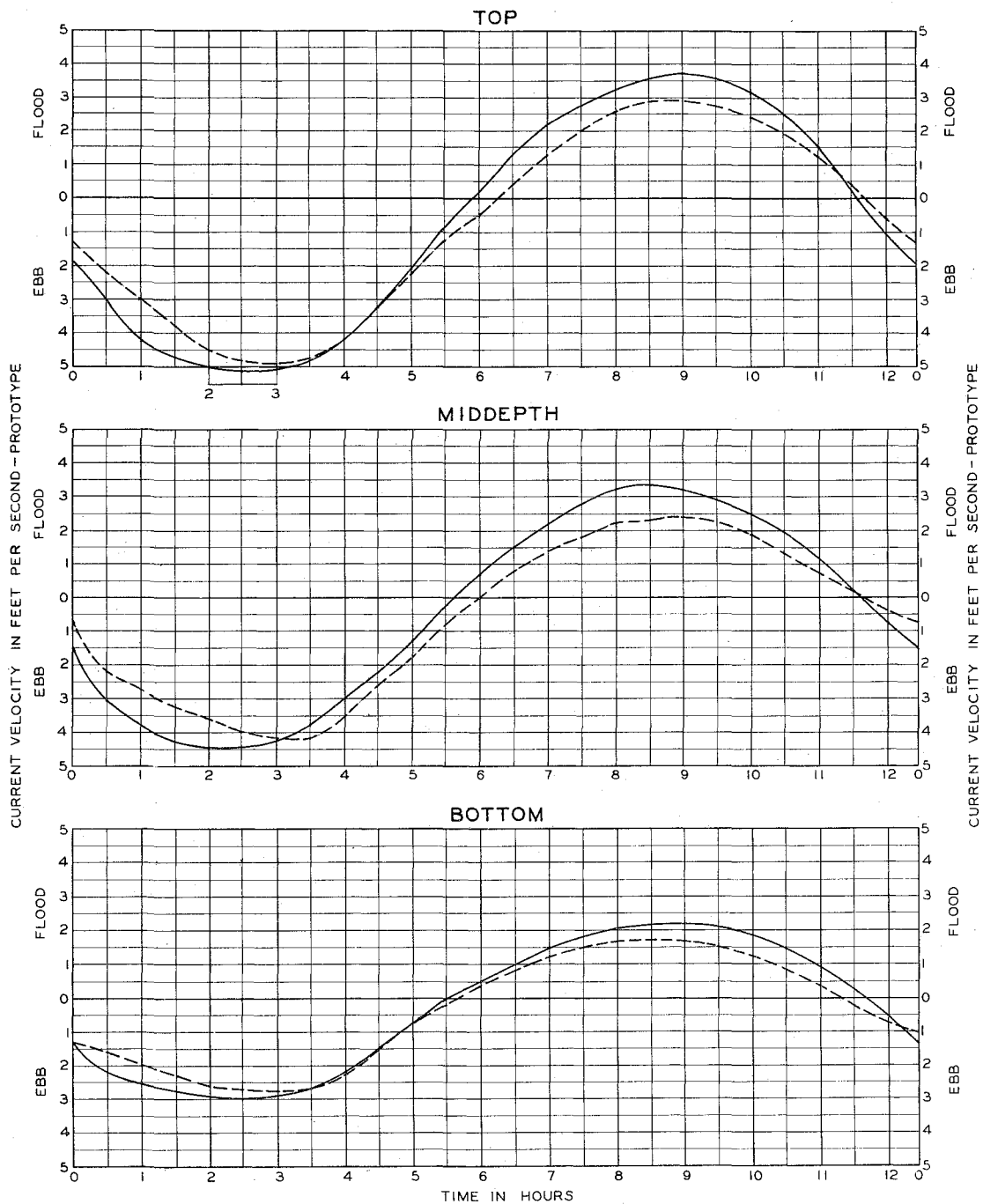
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 4

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

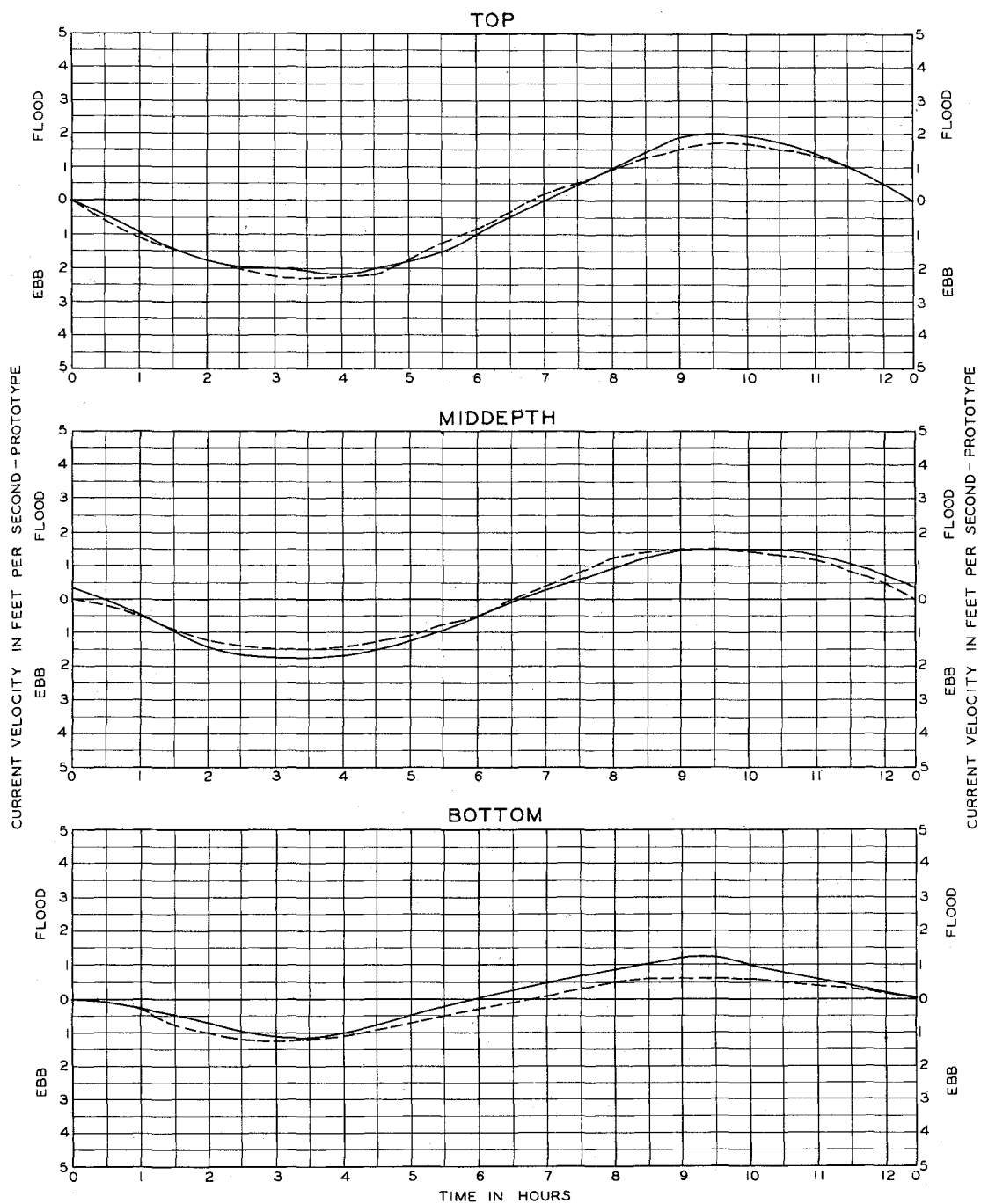
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 5

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

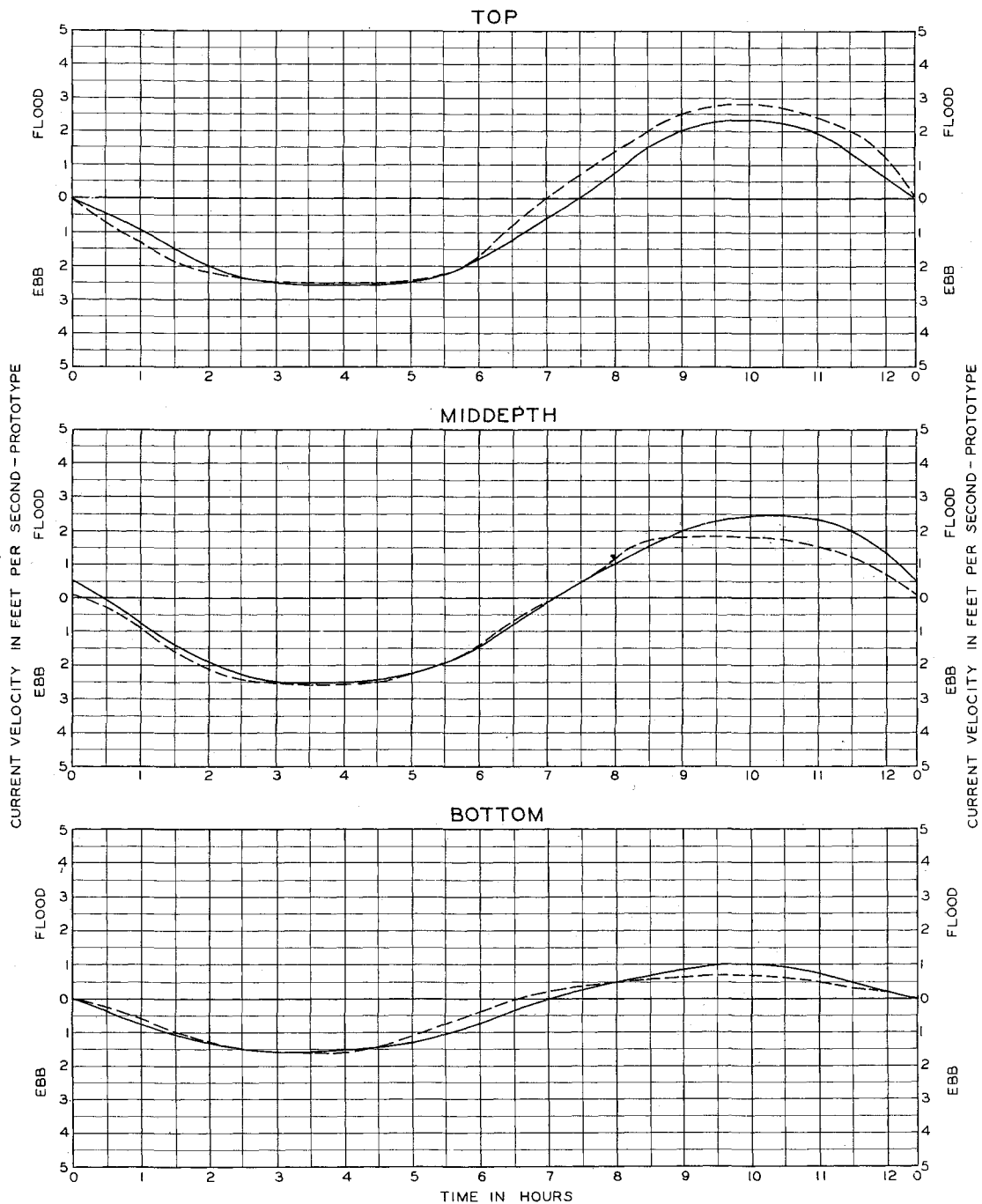
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 6

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

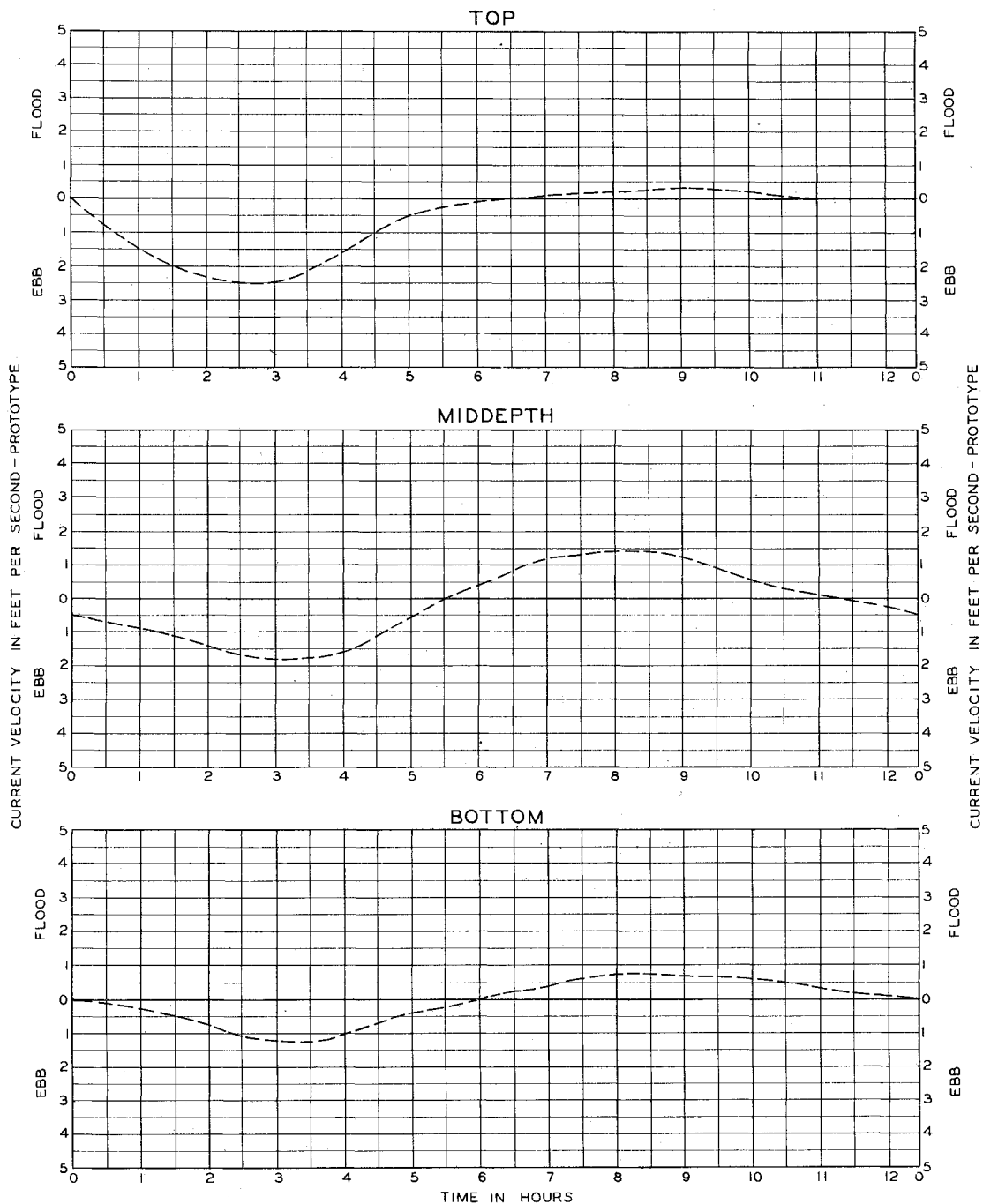
#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 7

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

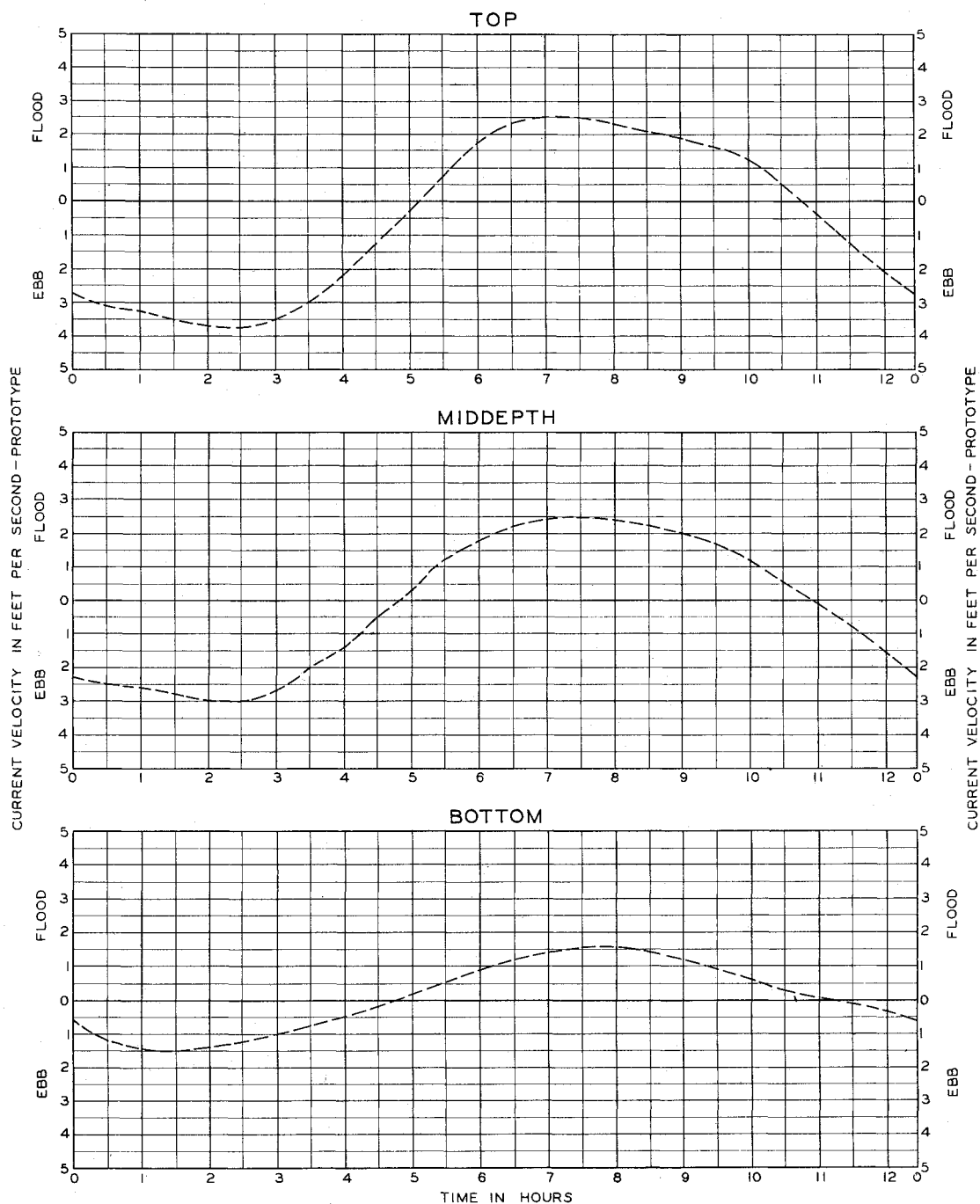
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 11

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

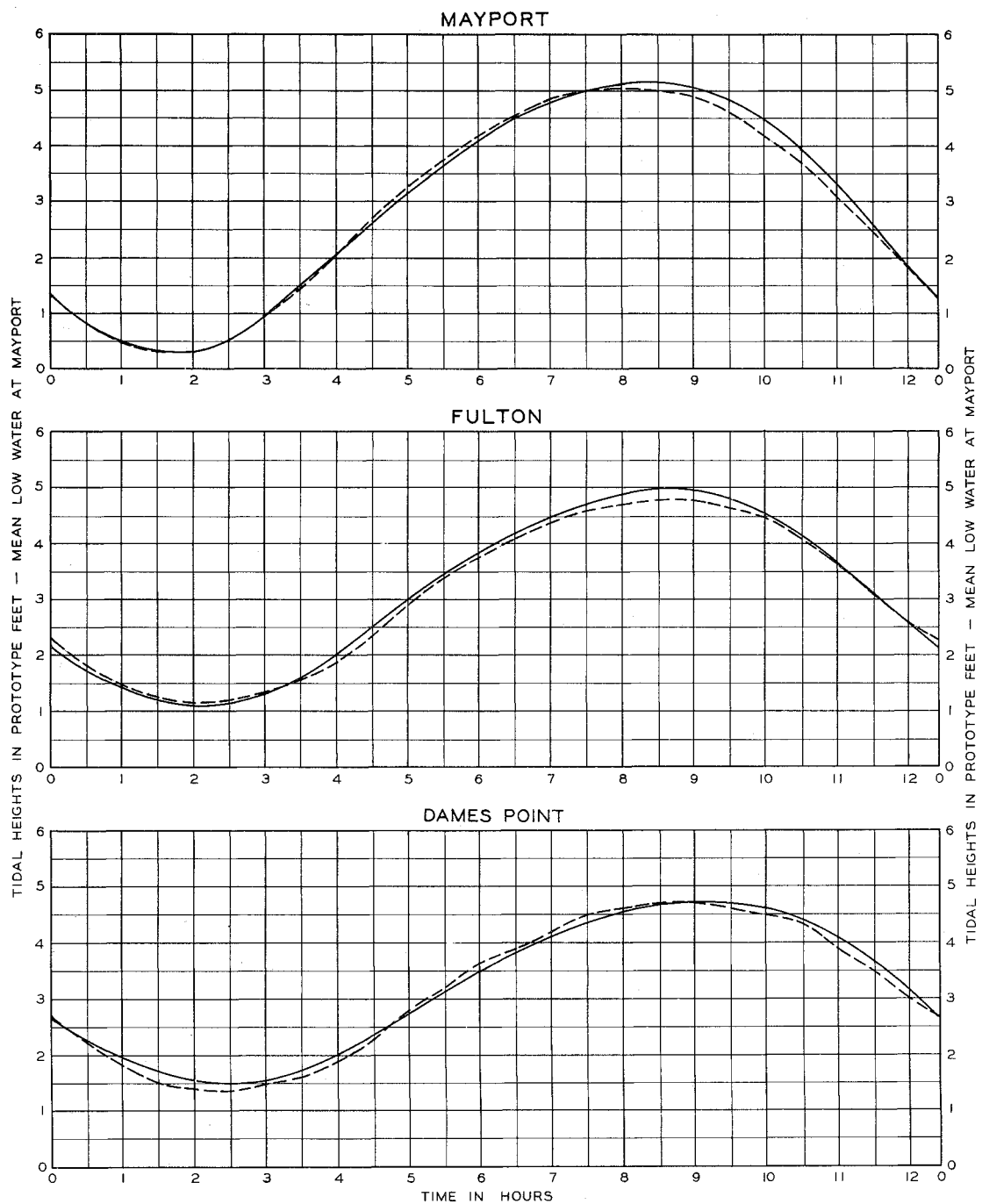
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN A-2 STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

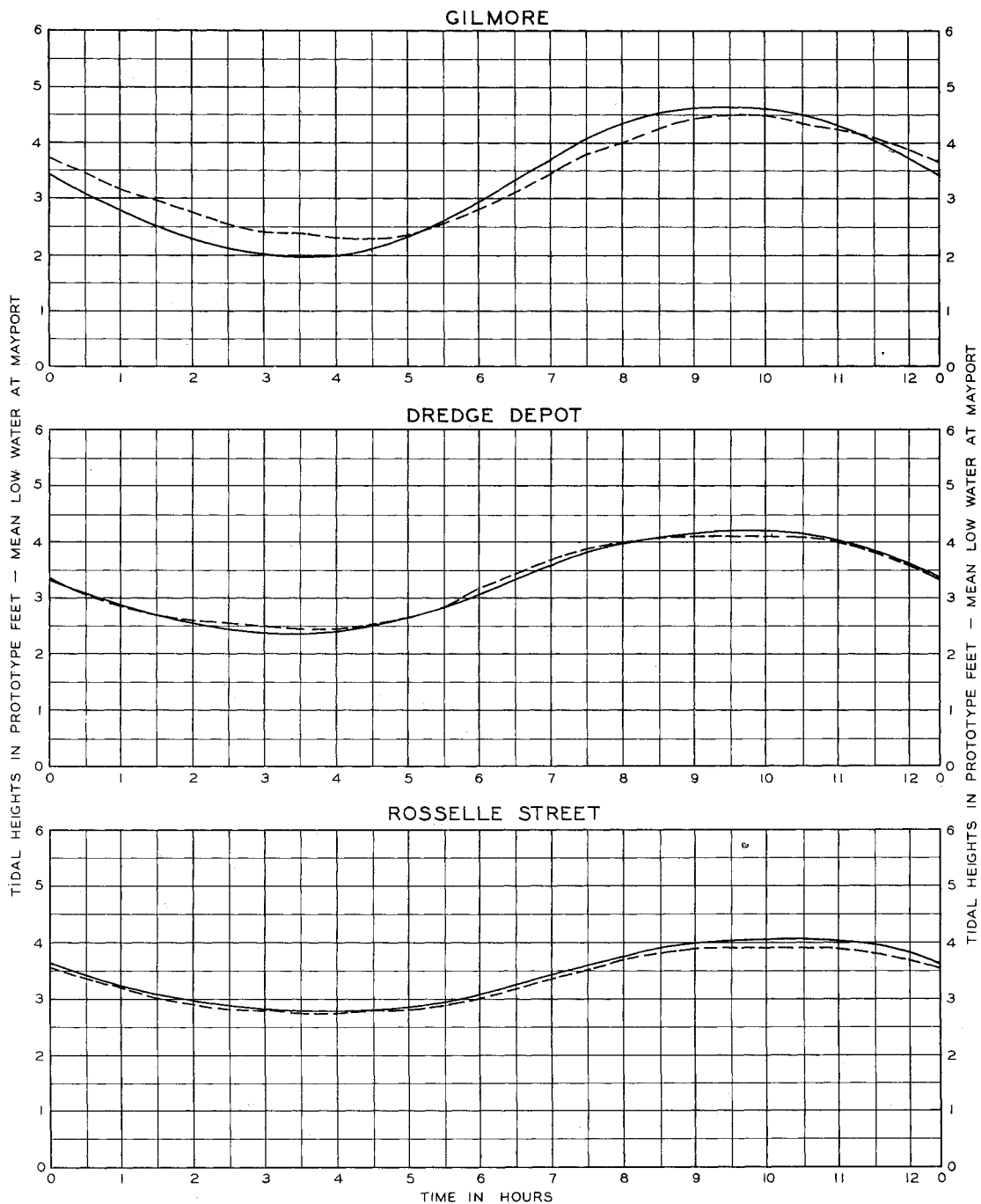
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST TIDAL HEIGHTS  
- - - PLAN TIDAL HEIGHTS

NOTE: SEE PLATE 57 FOR ELEMENTS OF PLAN A-3 AND PLATE 3 FOR LOCATION OF GAGES  
TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-3



#### TEST DATA

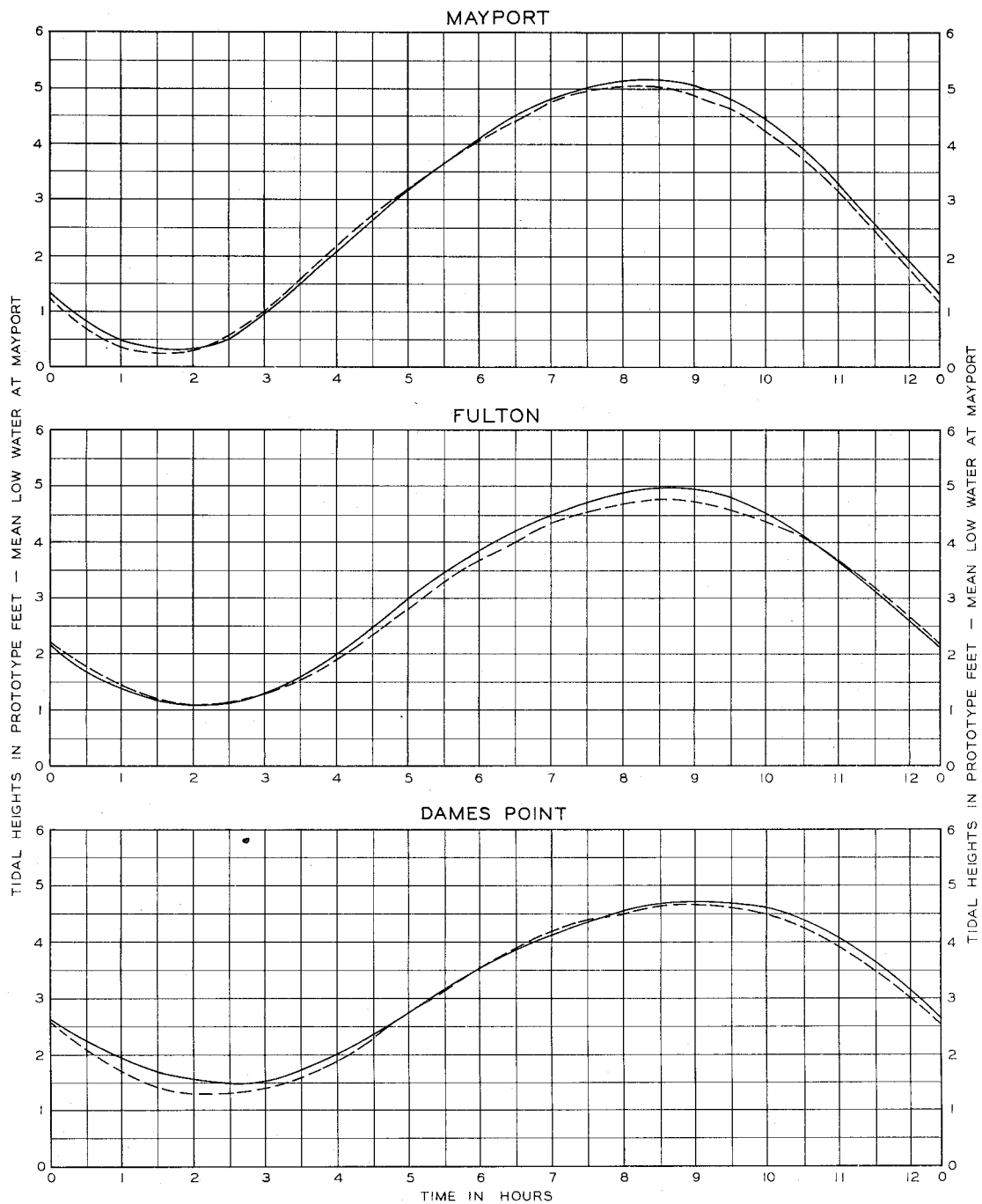
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN A-3



#### TEST DATA

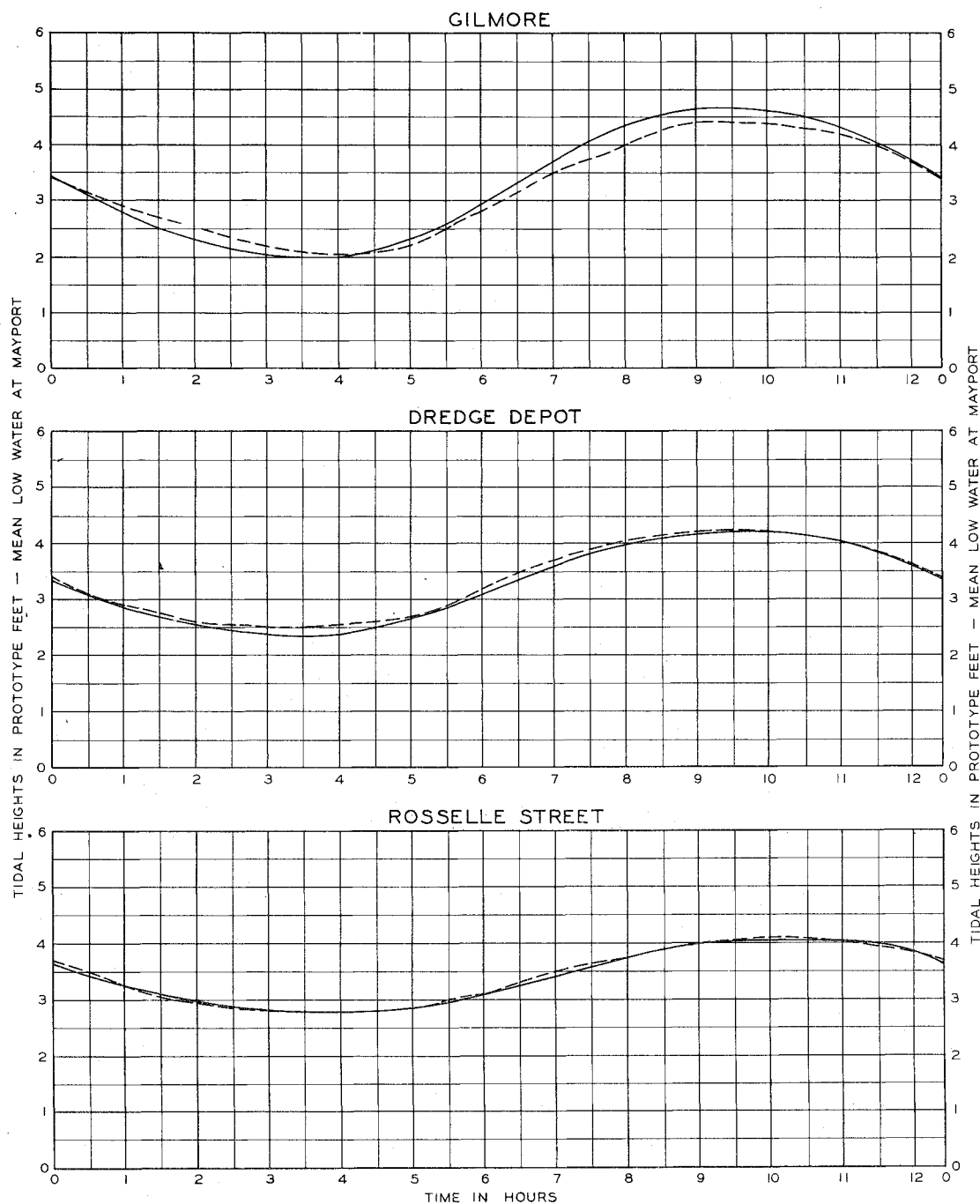
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN B-1



#### TEST DATA

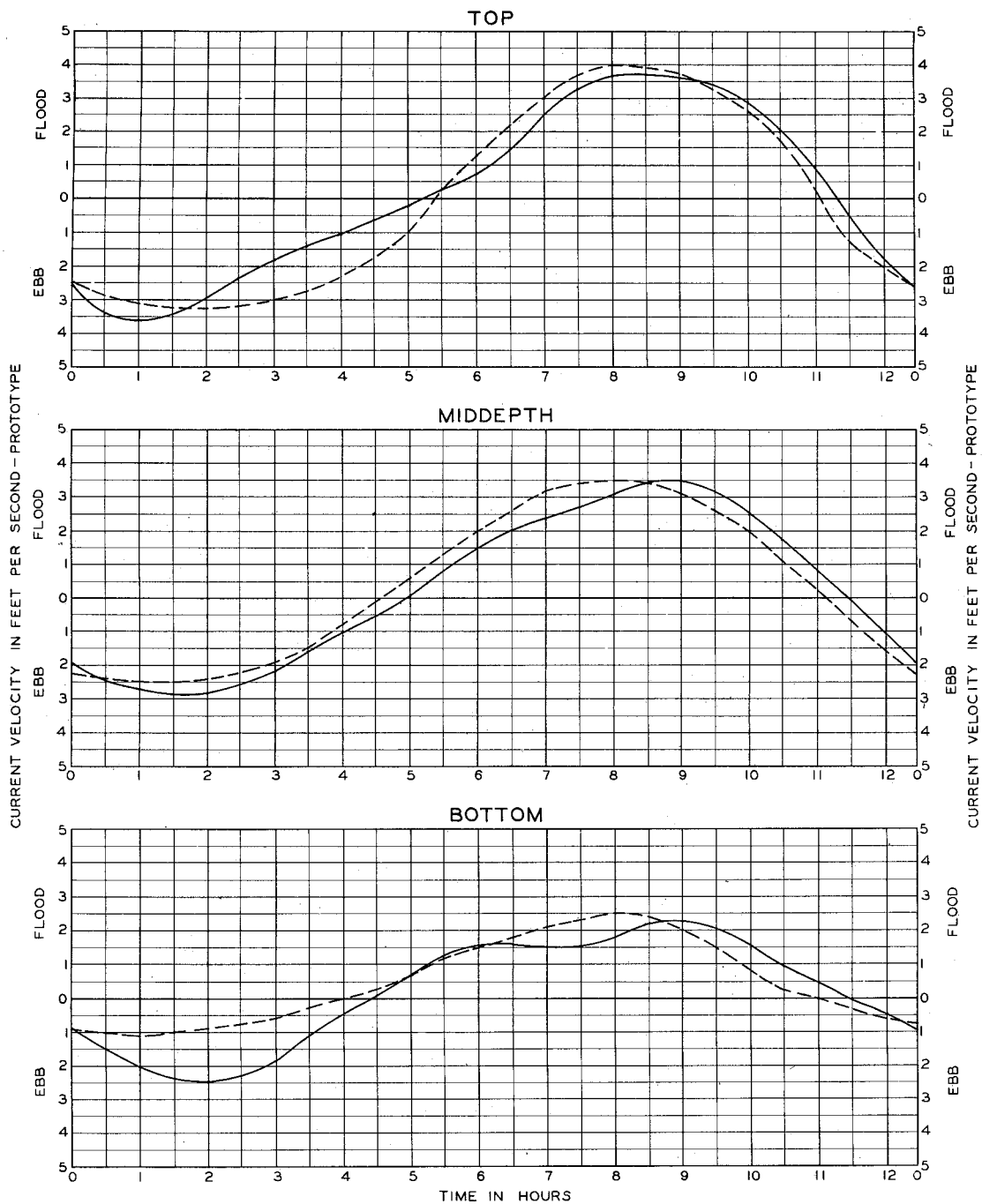
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN B-1



#### TEST DATA

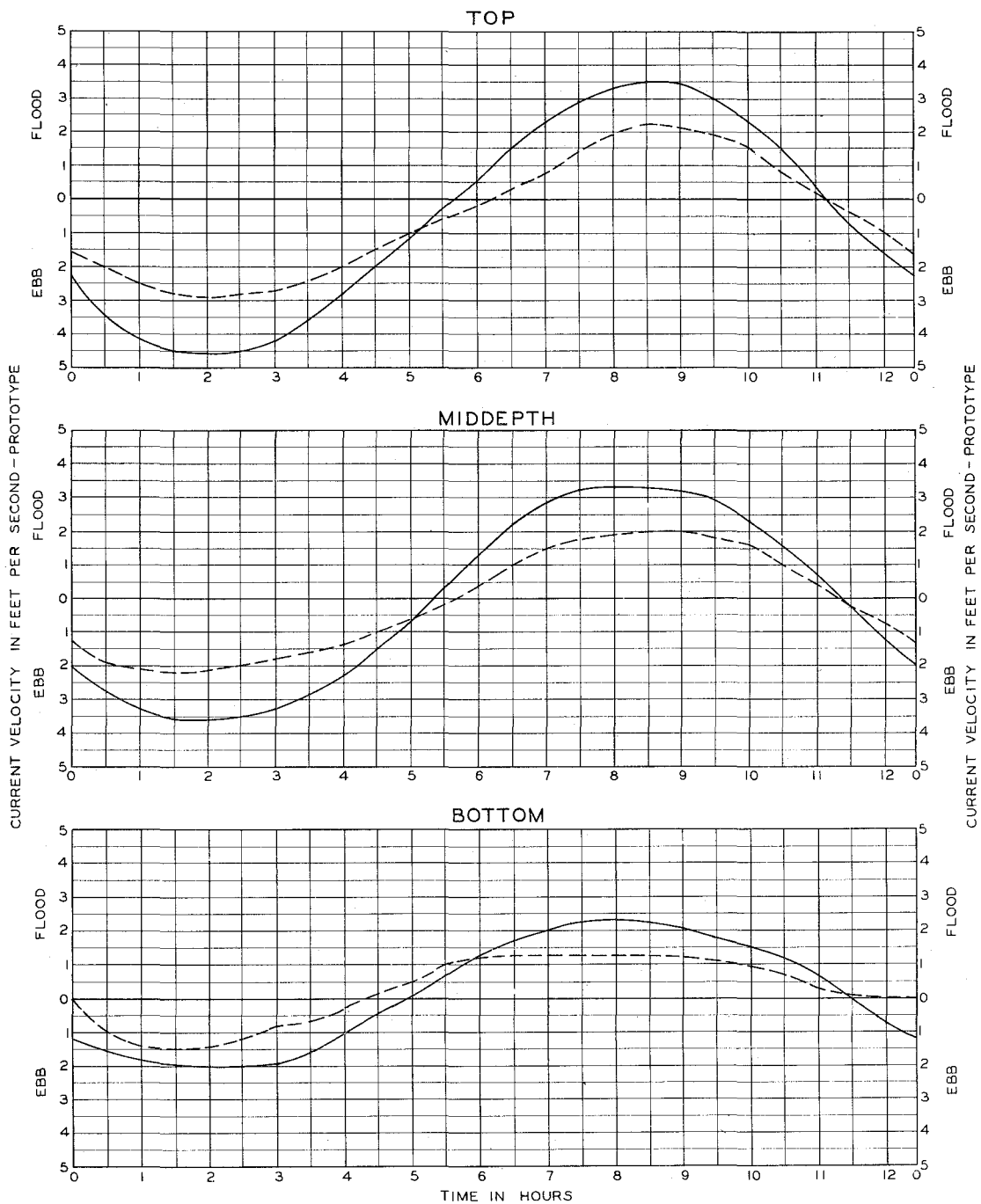
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN B-1 STATION 2

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

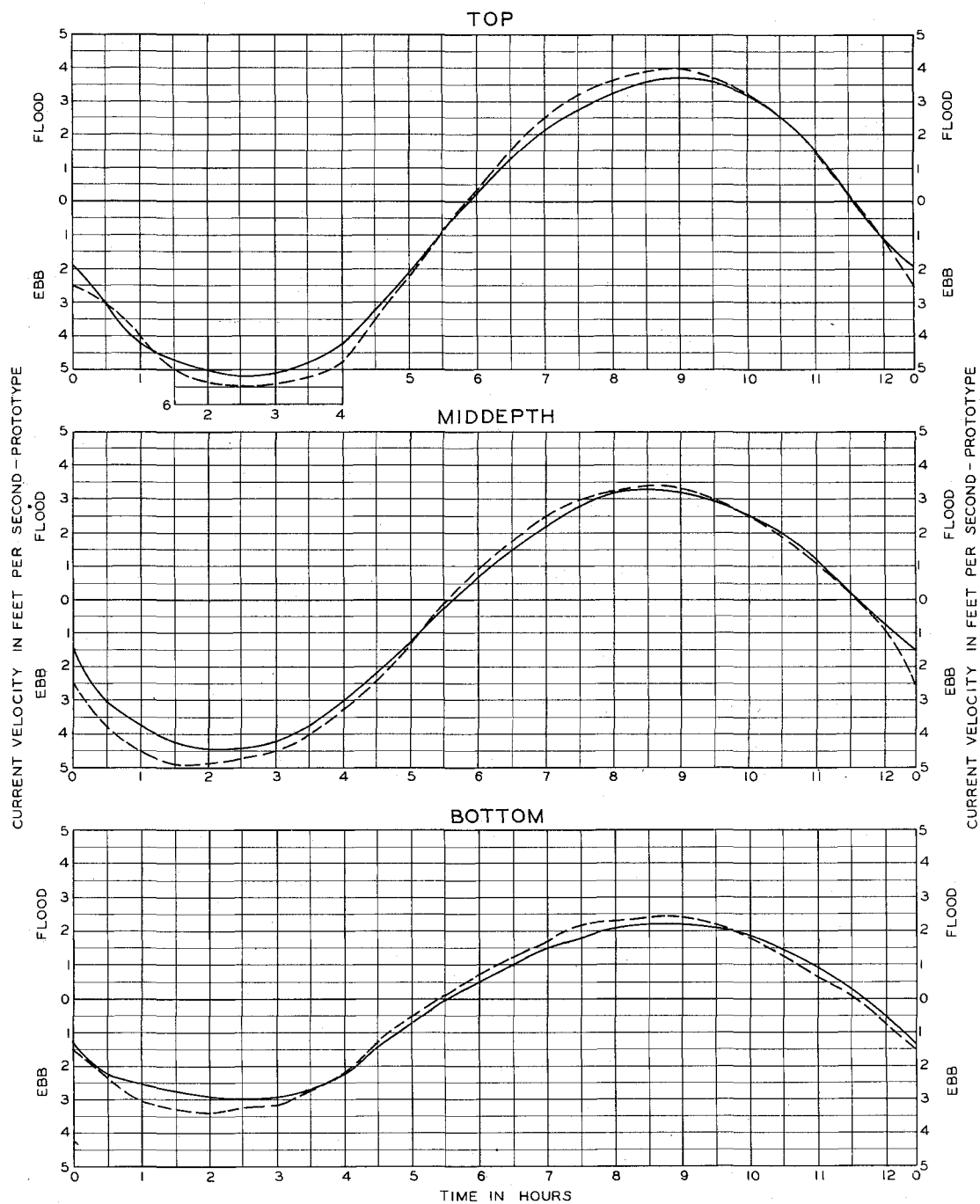
#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN B-1 STATION 4

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

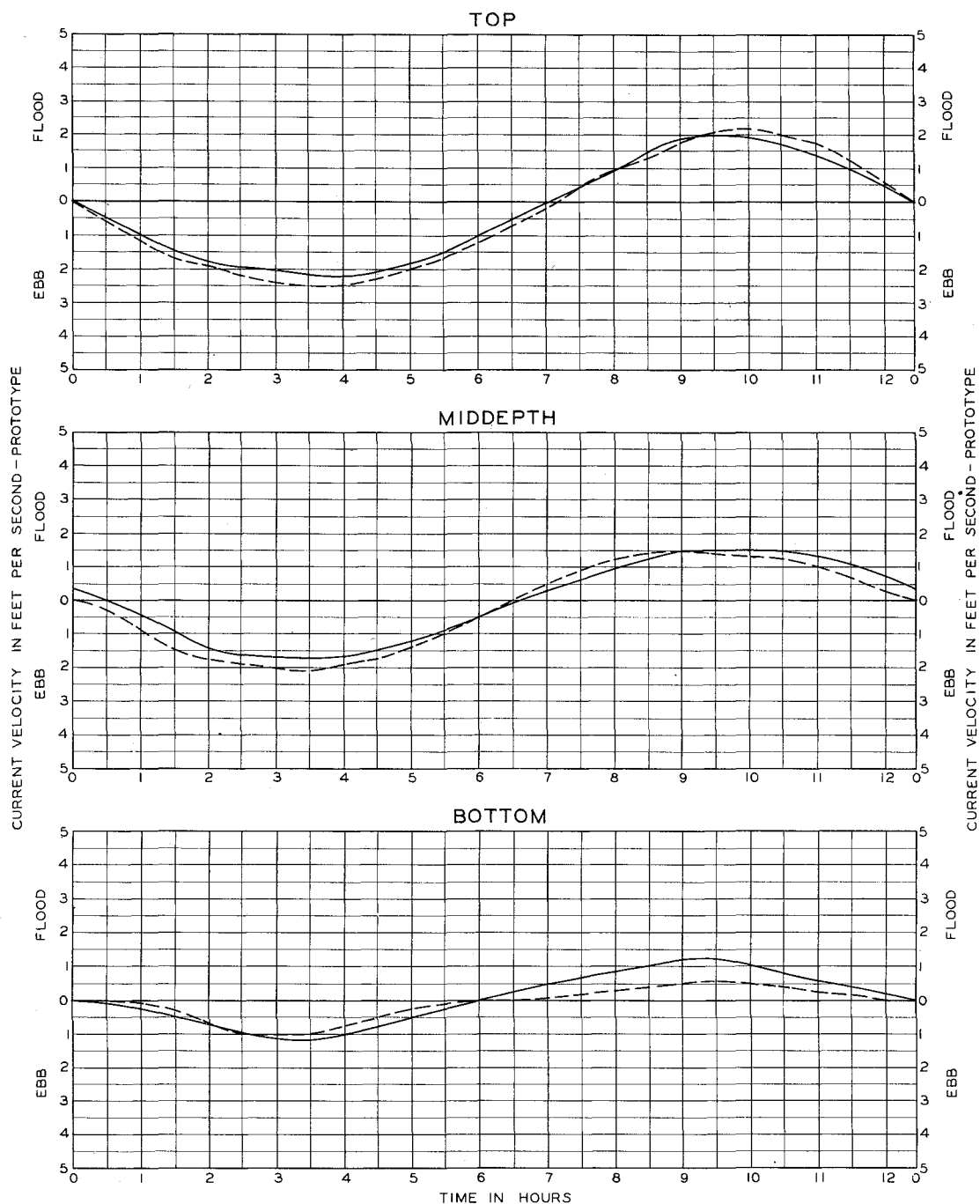
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN B-1 STATION 5

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



**TEST DATA**

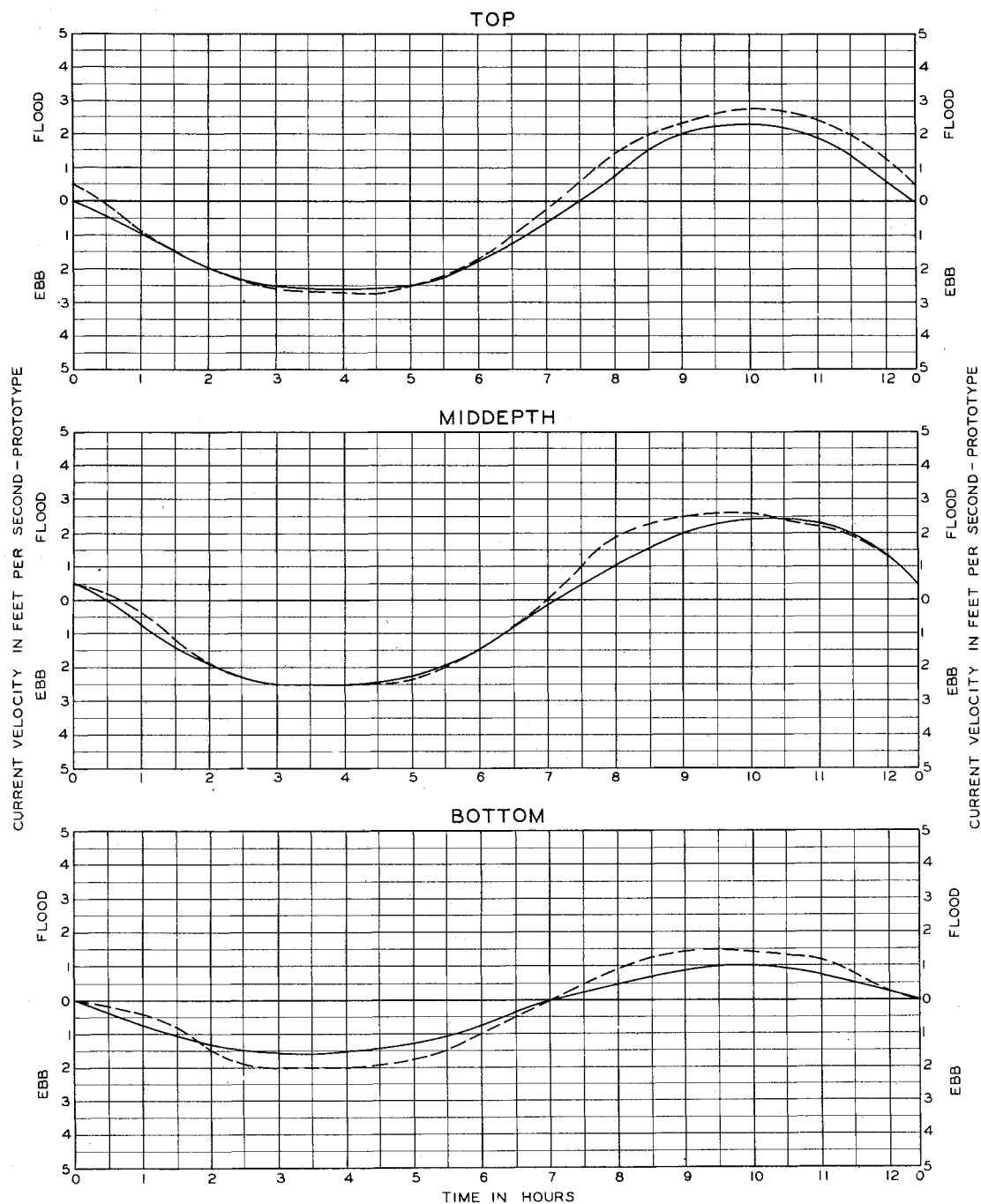
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

**LEGEND**

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

**VELOCITY CURVES  
PLAN B-1  
STATION 6**

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



**TEST DATA**

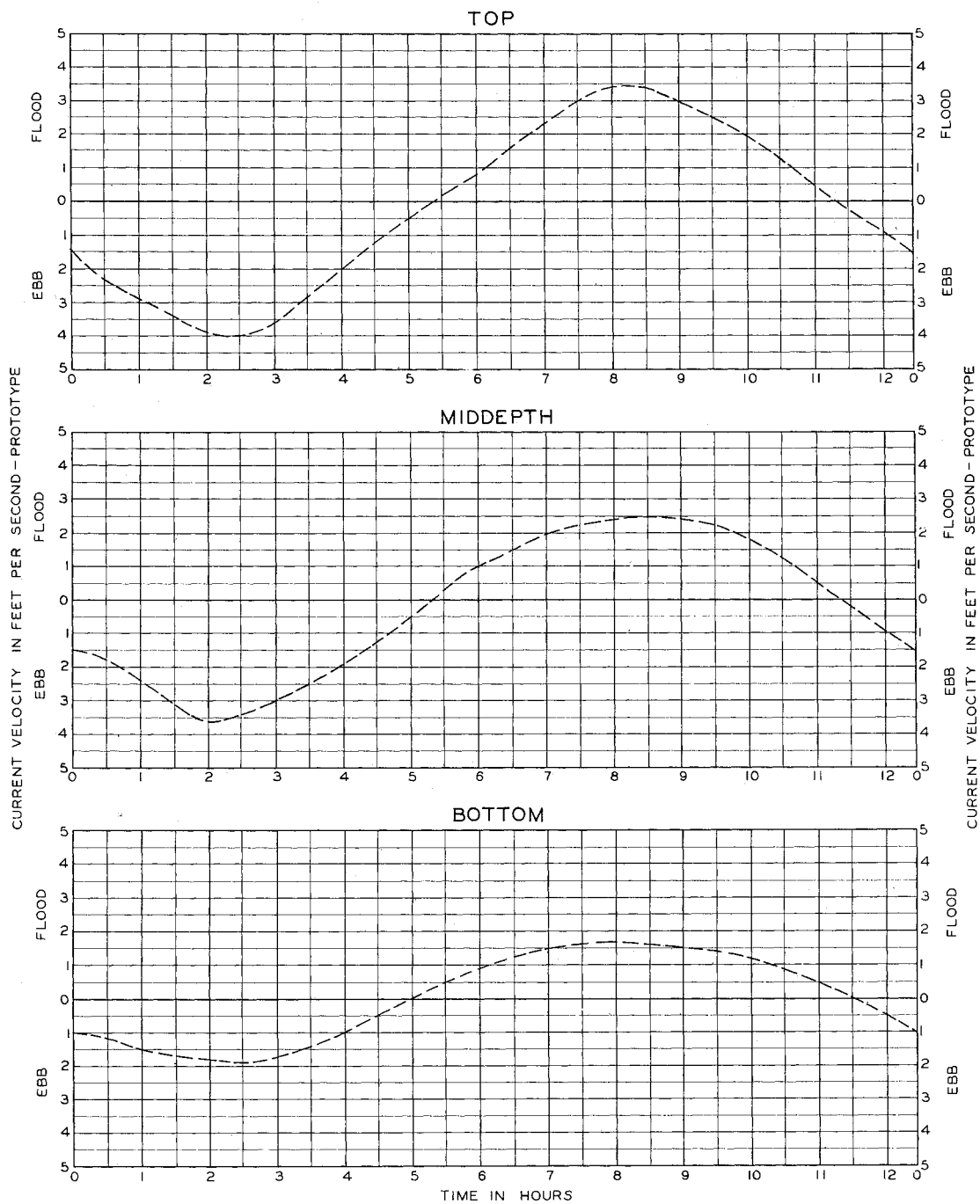
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

**LEGEND**

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

**VELOCITY CURVES  
PLAN B-1  
STATION 7**

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

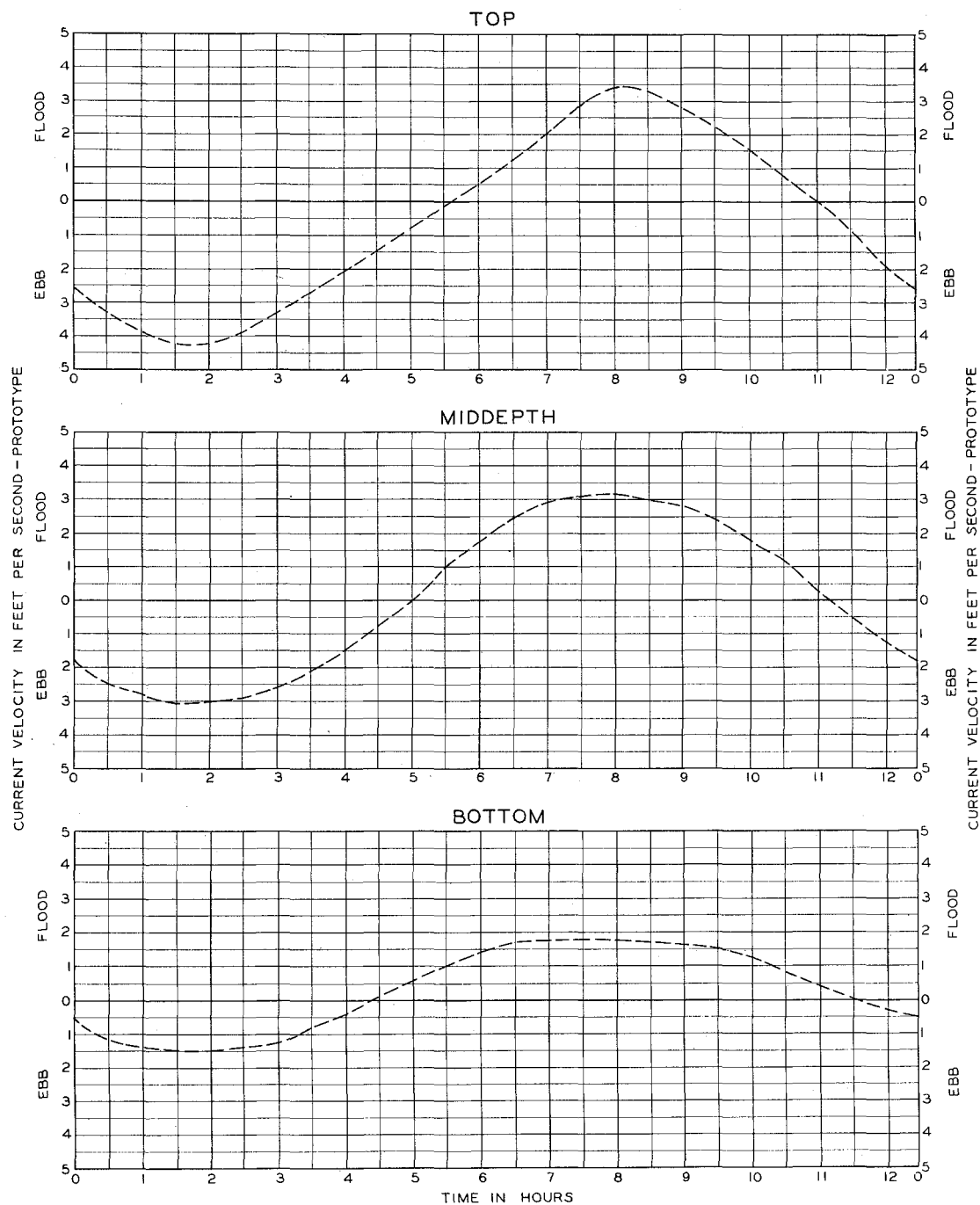
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

**VELOCITY CURVES  
PLAN B-1  
STATION 11**



#### TEST DATA

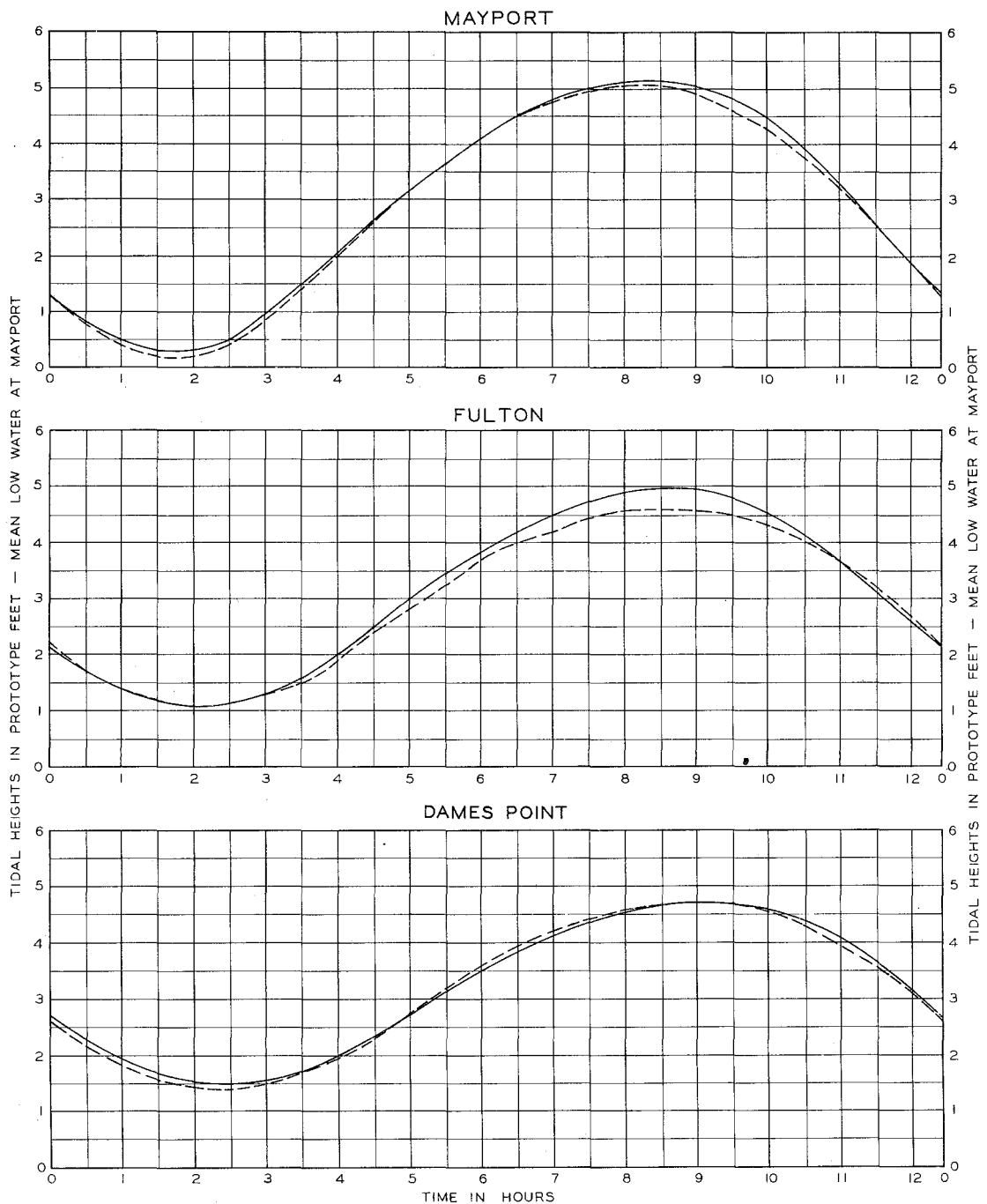
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

—— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN B-1 STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

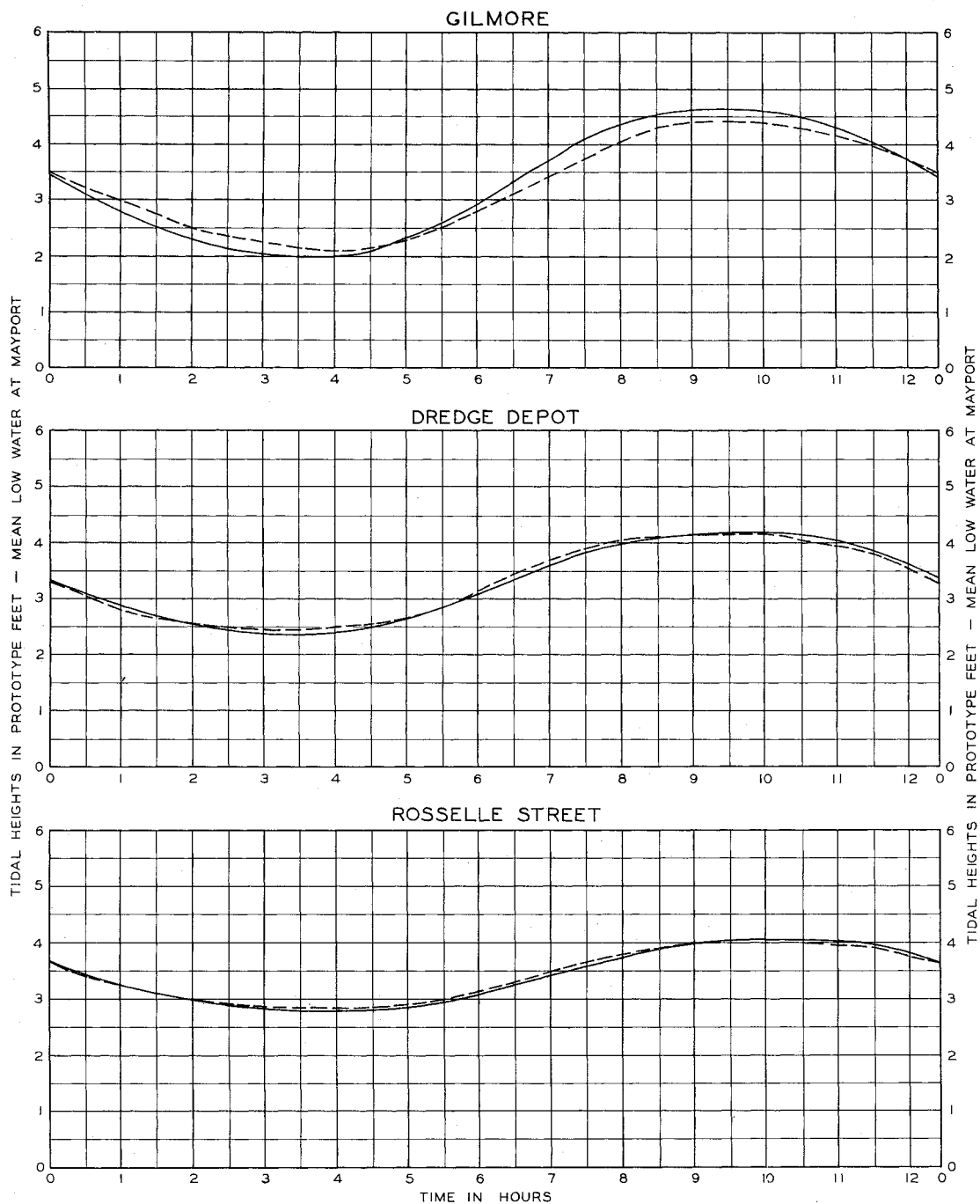
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BAST TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN C-1



#### TEST DATA

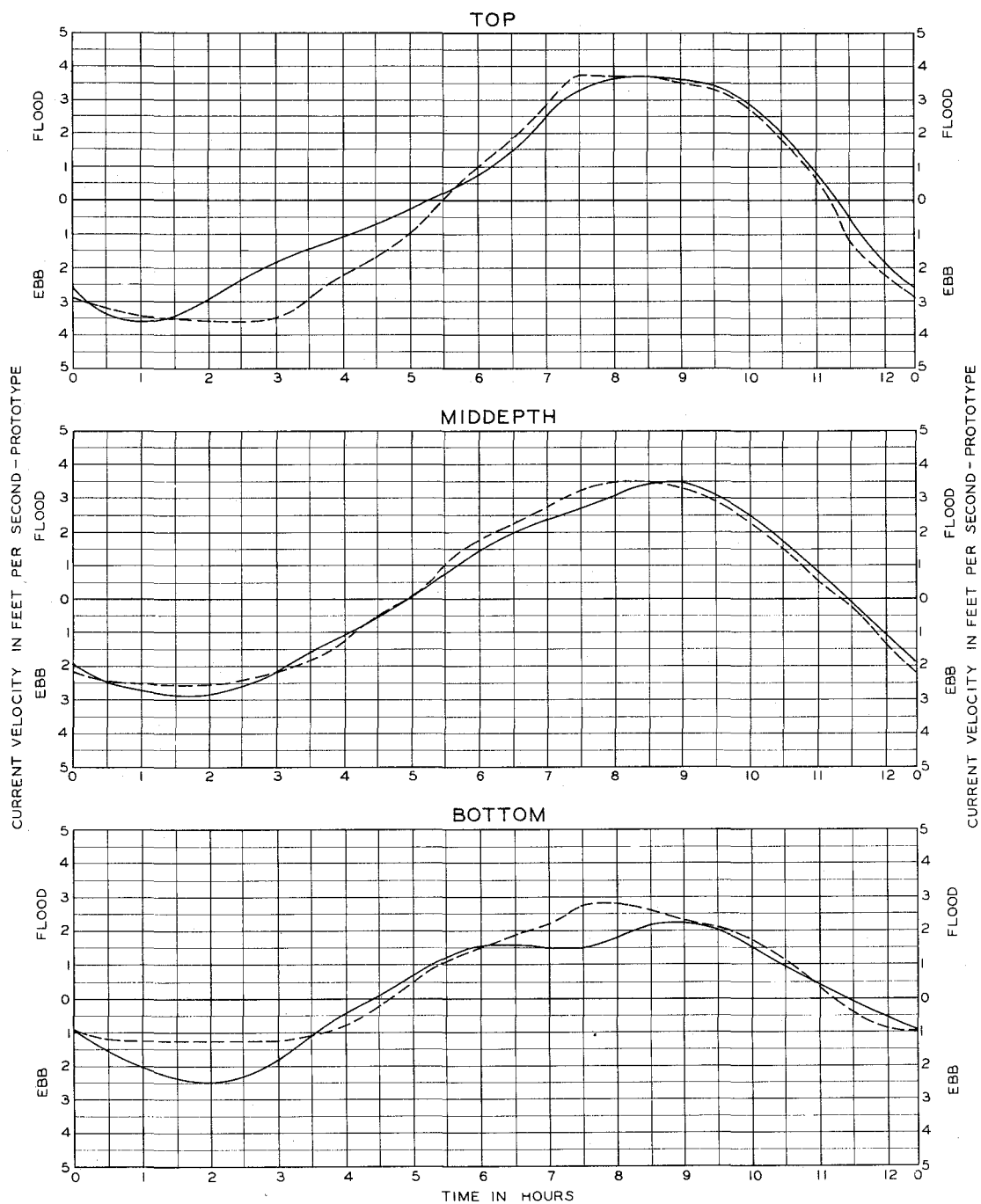
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN C-1



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

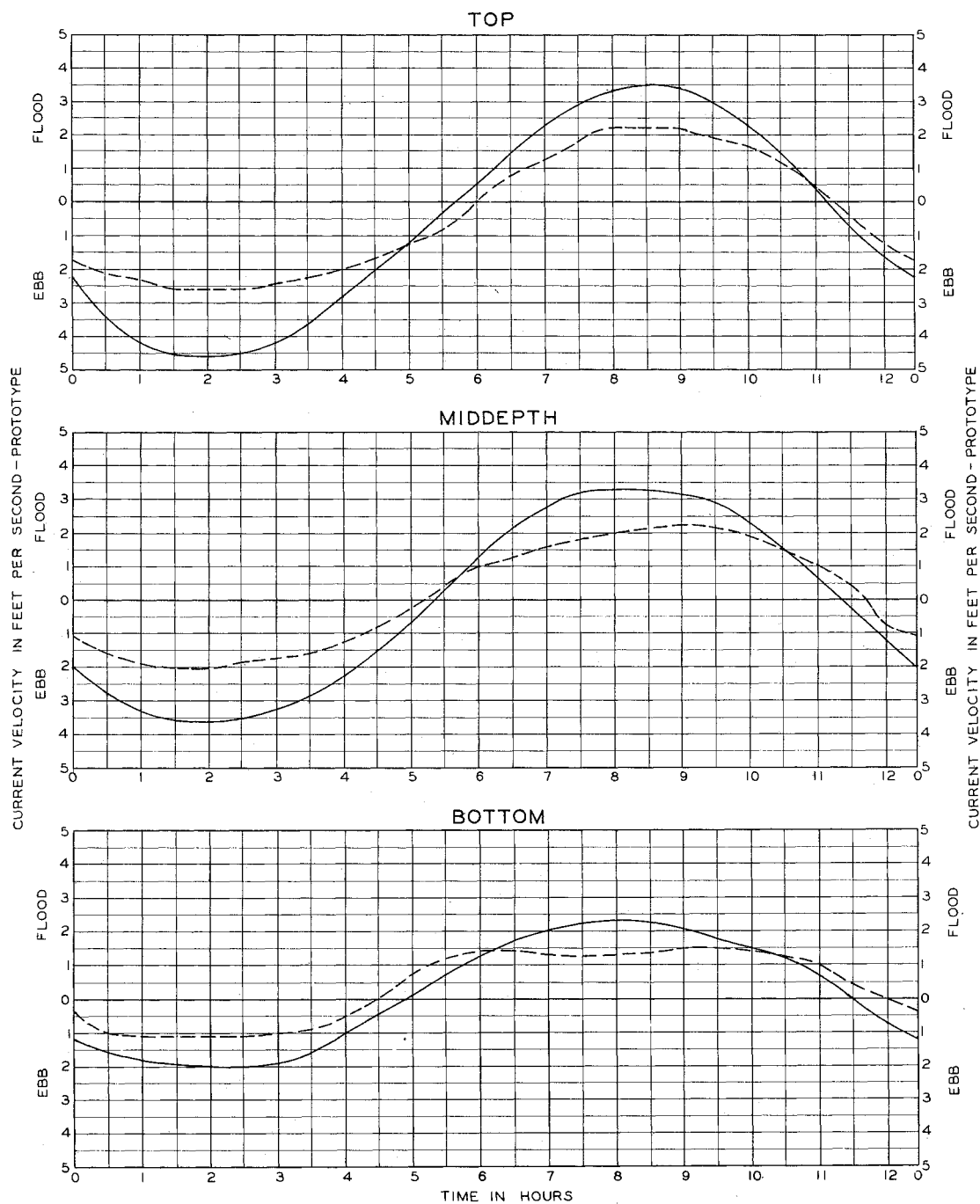
#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION 2

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

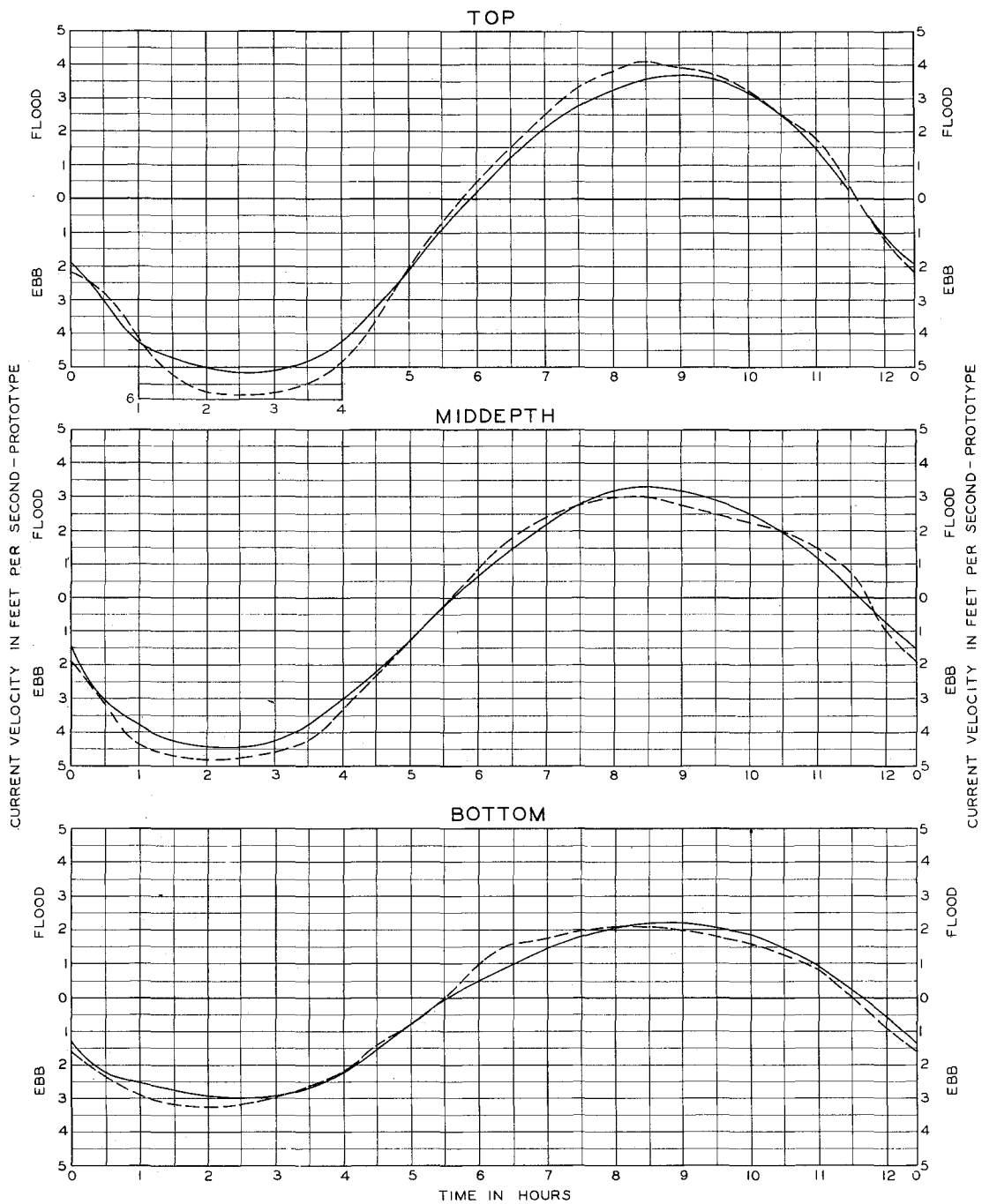
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION 4

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

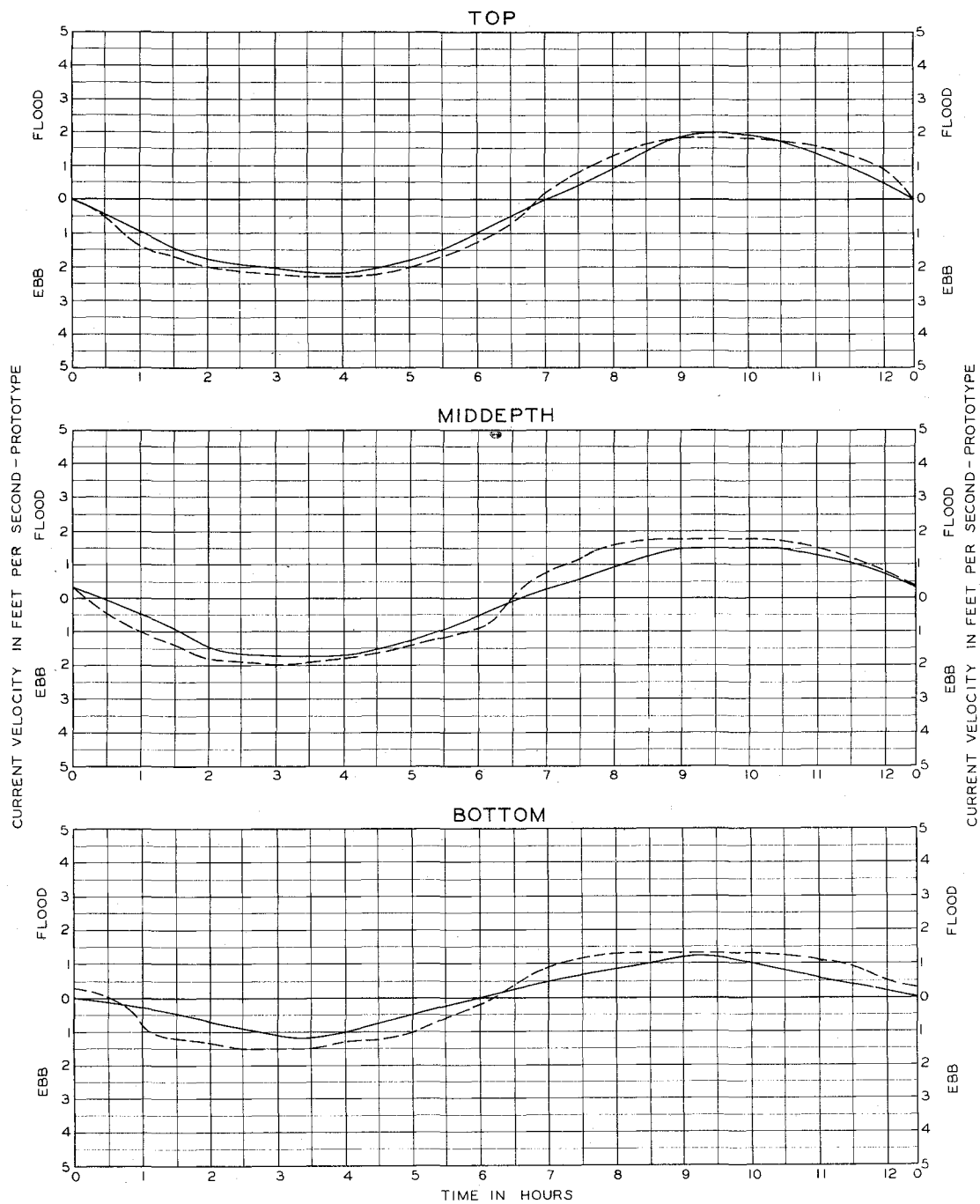
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

VELOCITY CURVES  
PLAN C-1  
STATION 5



#### TEST DATA

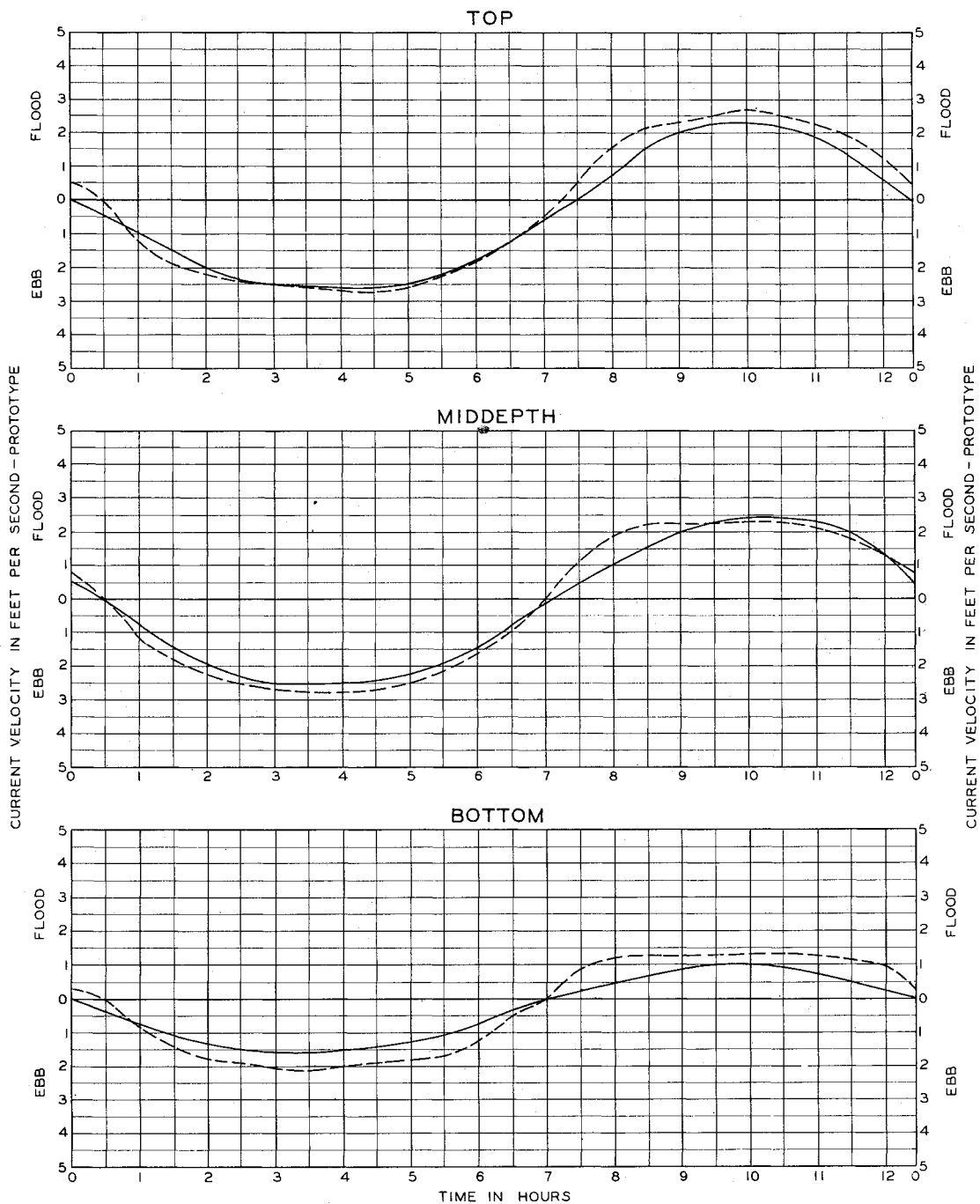
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION 6

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

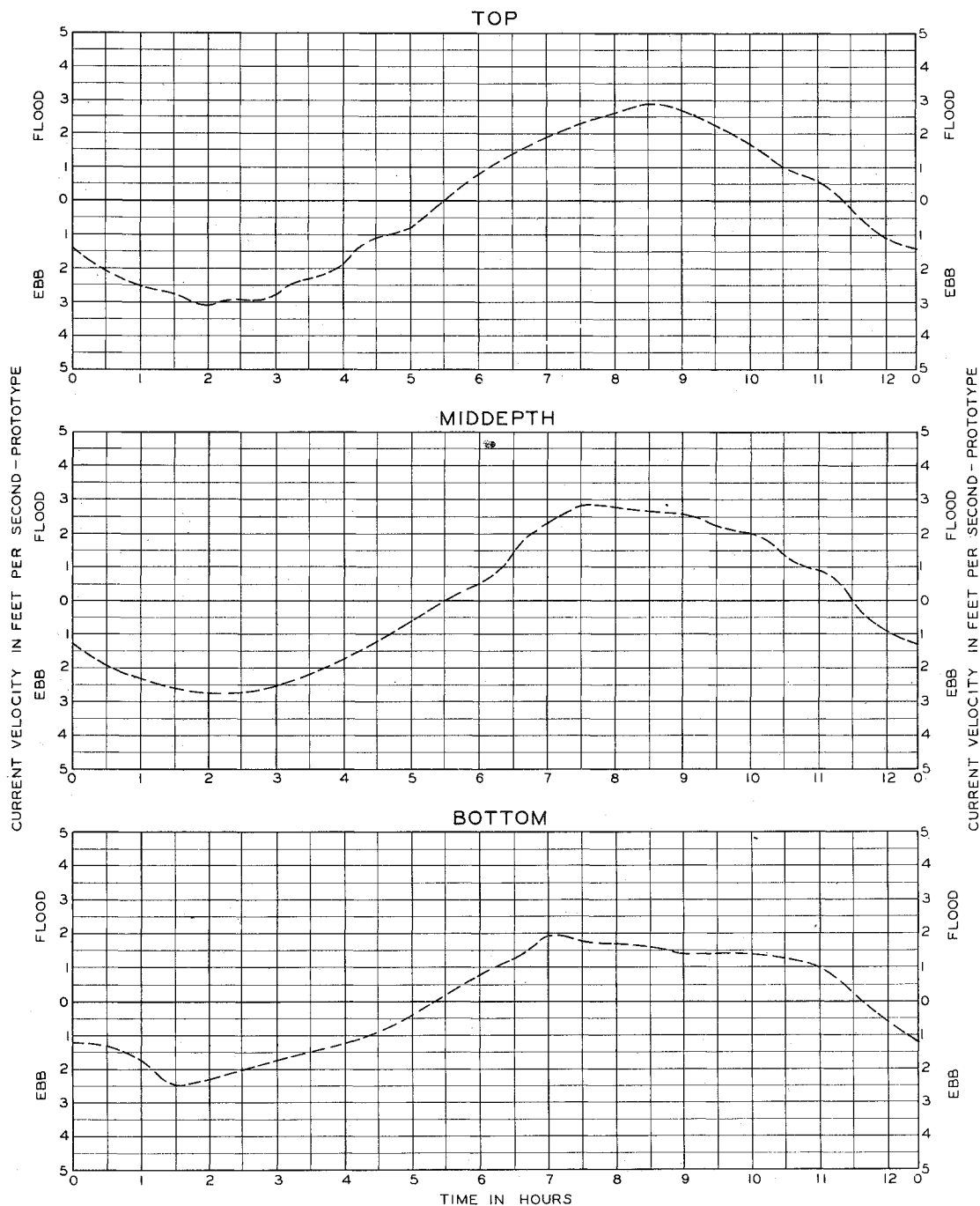
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION 7

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

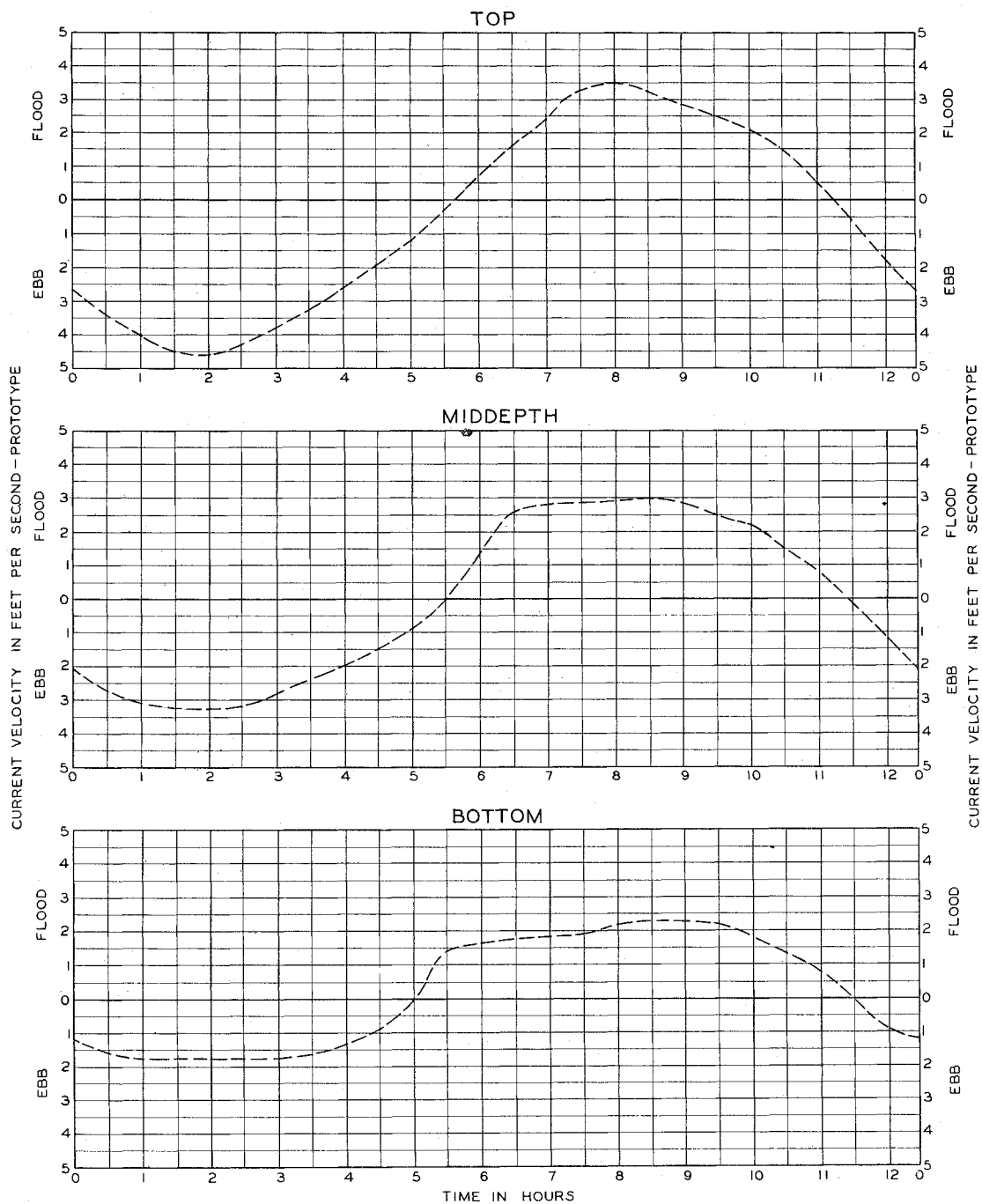
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION II

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

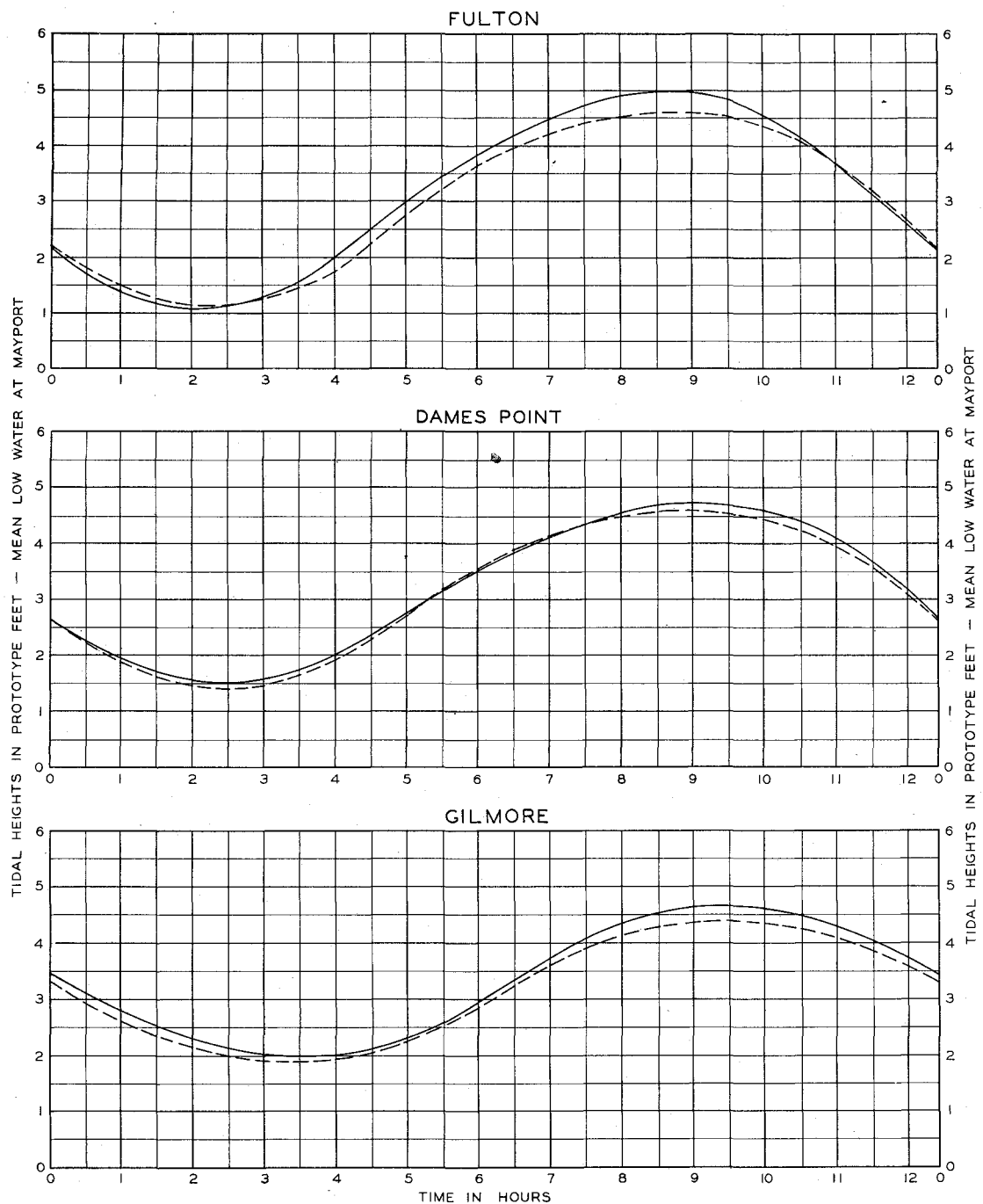
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-1 STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

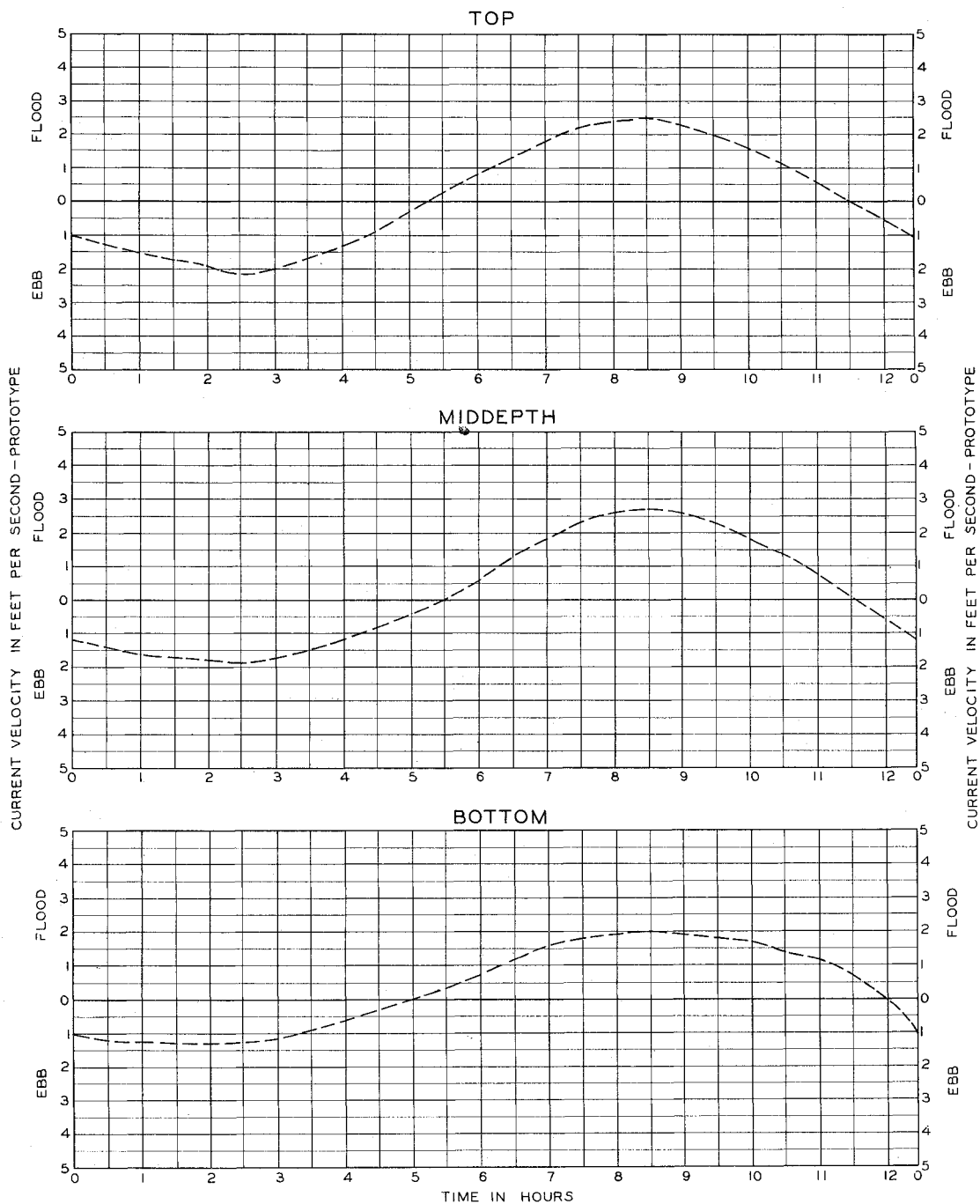
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN C-6



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

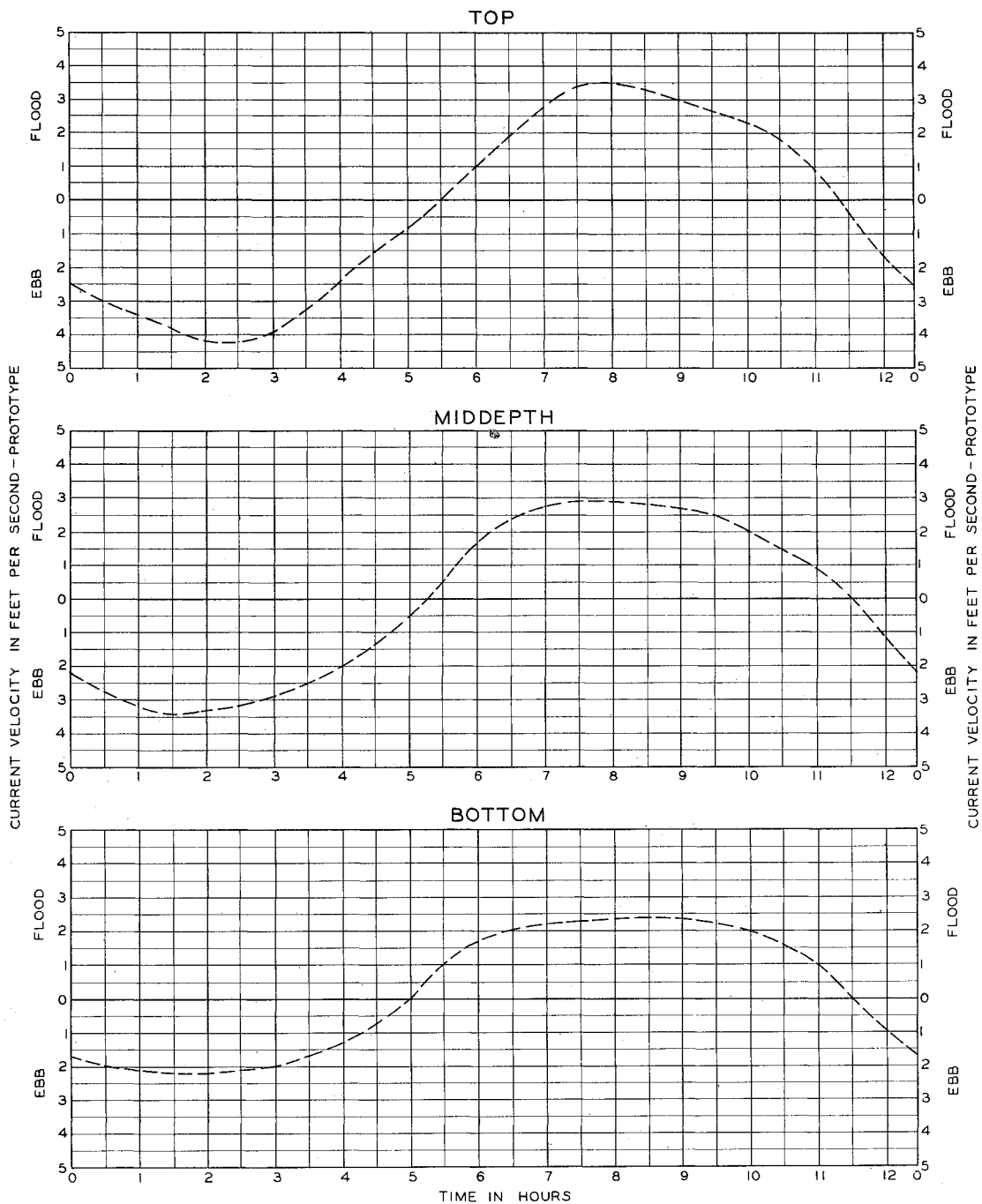
#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-6 STATION II

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

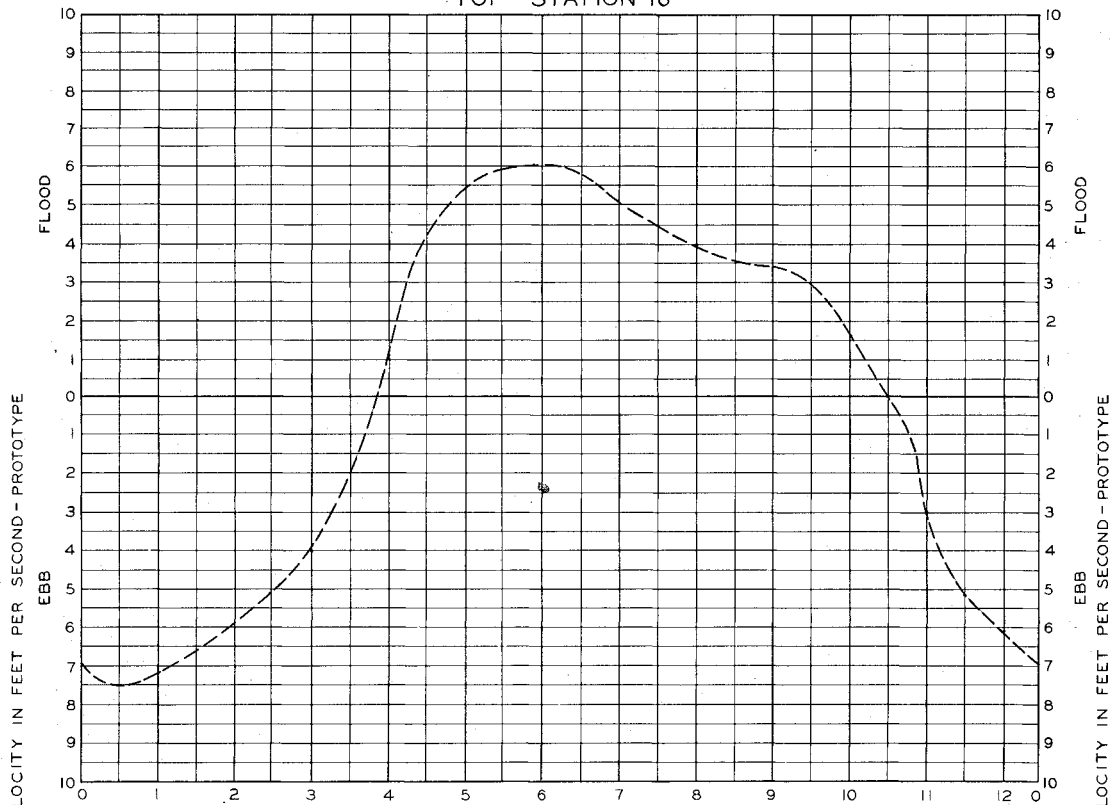
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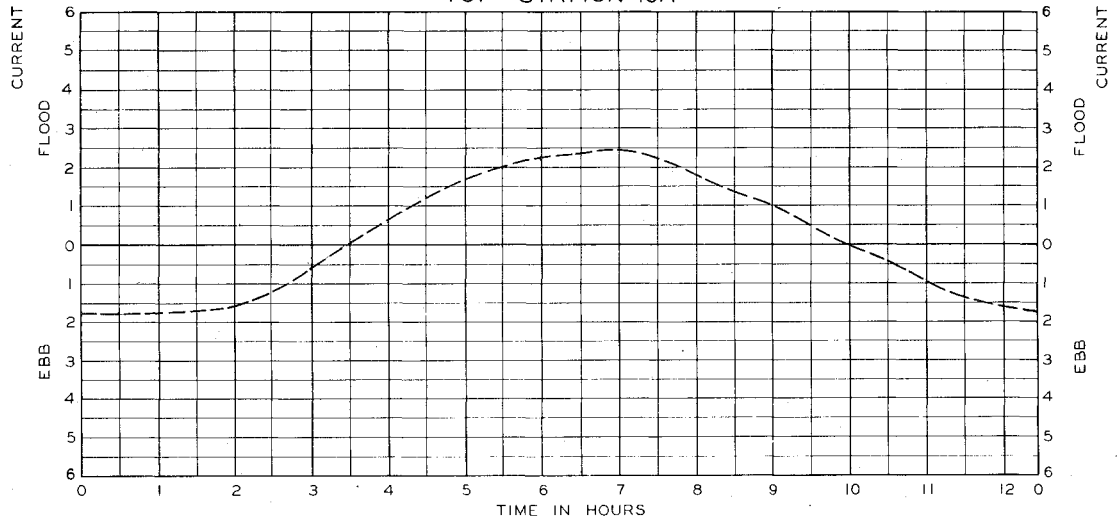
VELOCITY CURVES  
PLAN C-6  
STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TOP - STATION 16



TOP - STATION 16A



TEST DATA

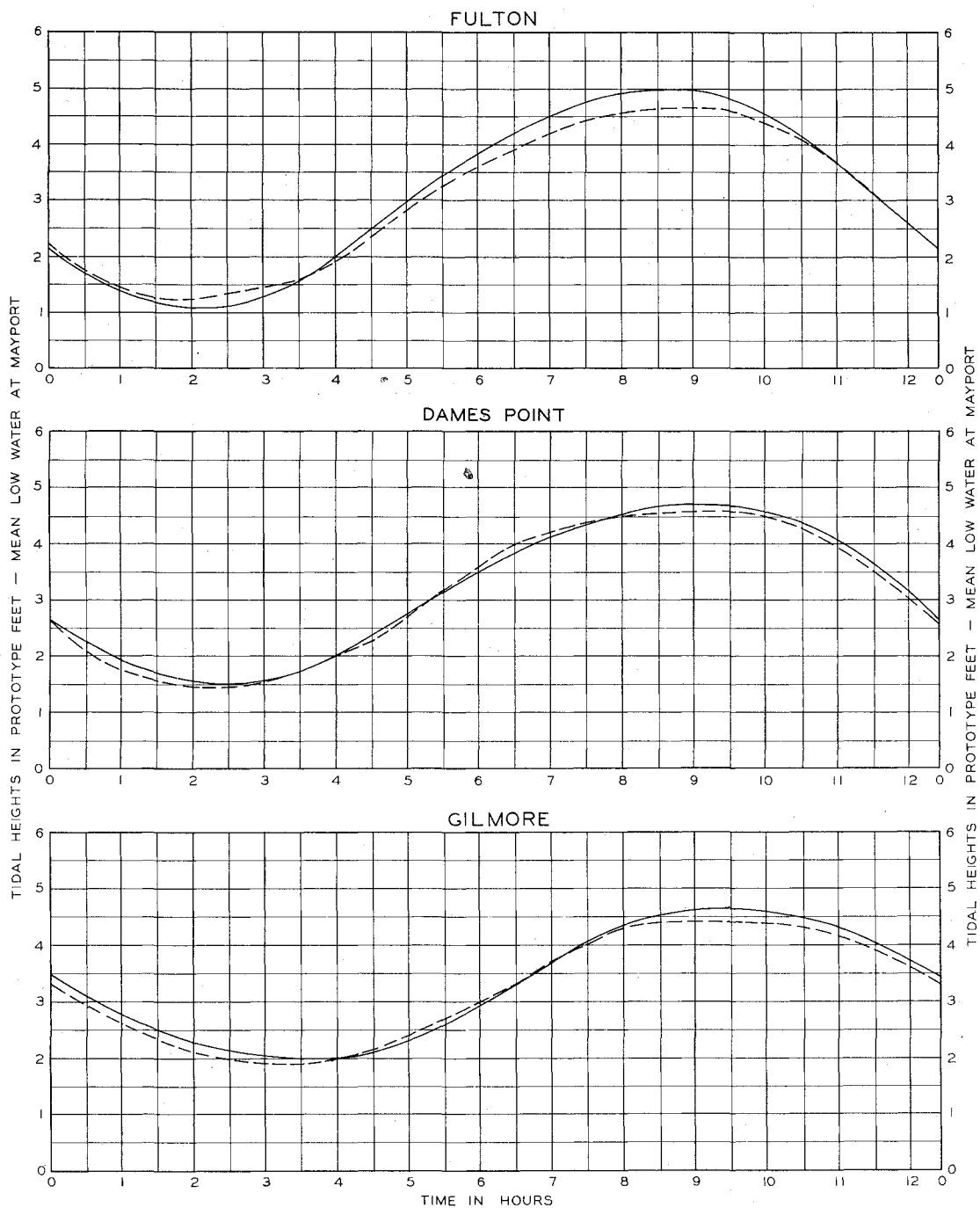
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

LEGEND

———— BASE TEST VELOCITY CURVES  
- - - - - PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN

VELOCITY CURVES  
PLAN C-6



#### TEST DATA

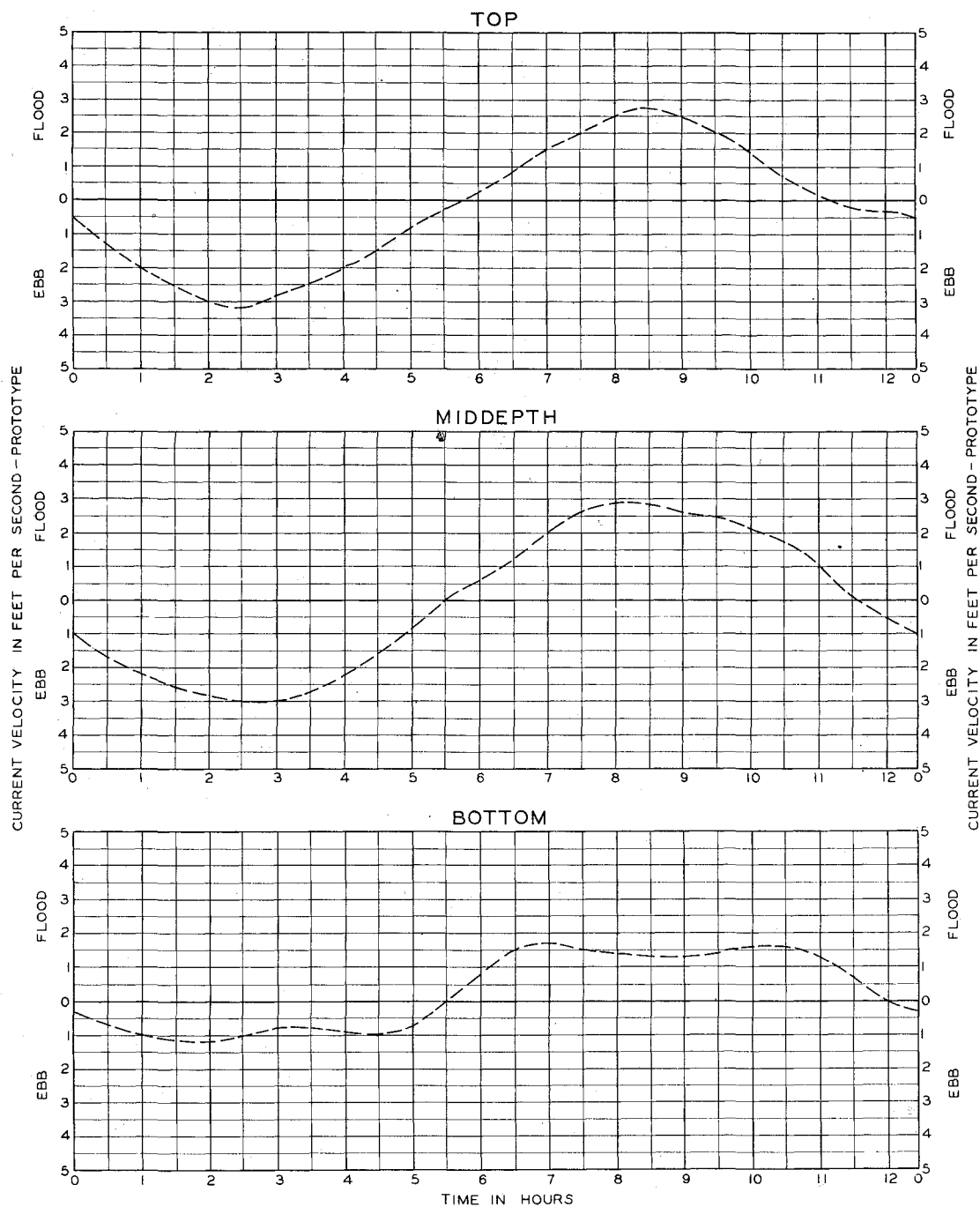
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST TIDAL HEIGHTS  
----- PLAN TIDAL HEIGHTS

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

TIDAL HEIGHTS  
PLAN C-7



#### TEST DATA

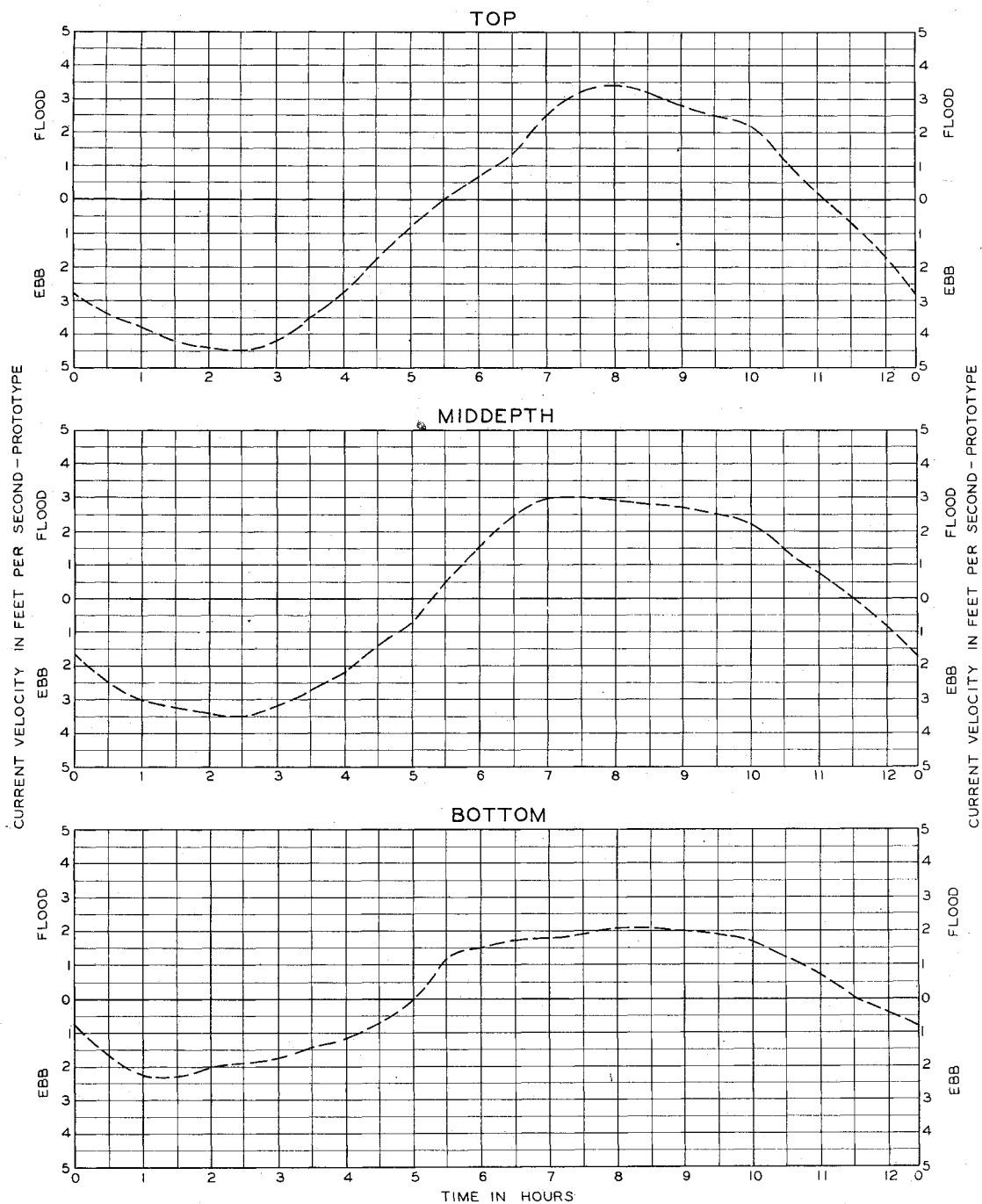
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-7 STATION II

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

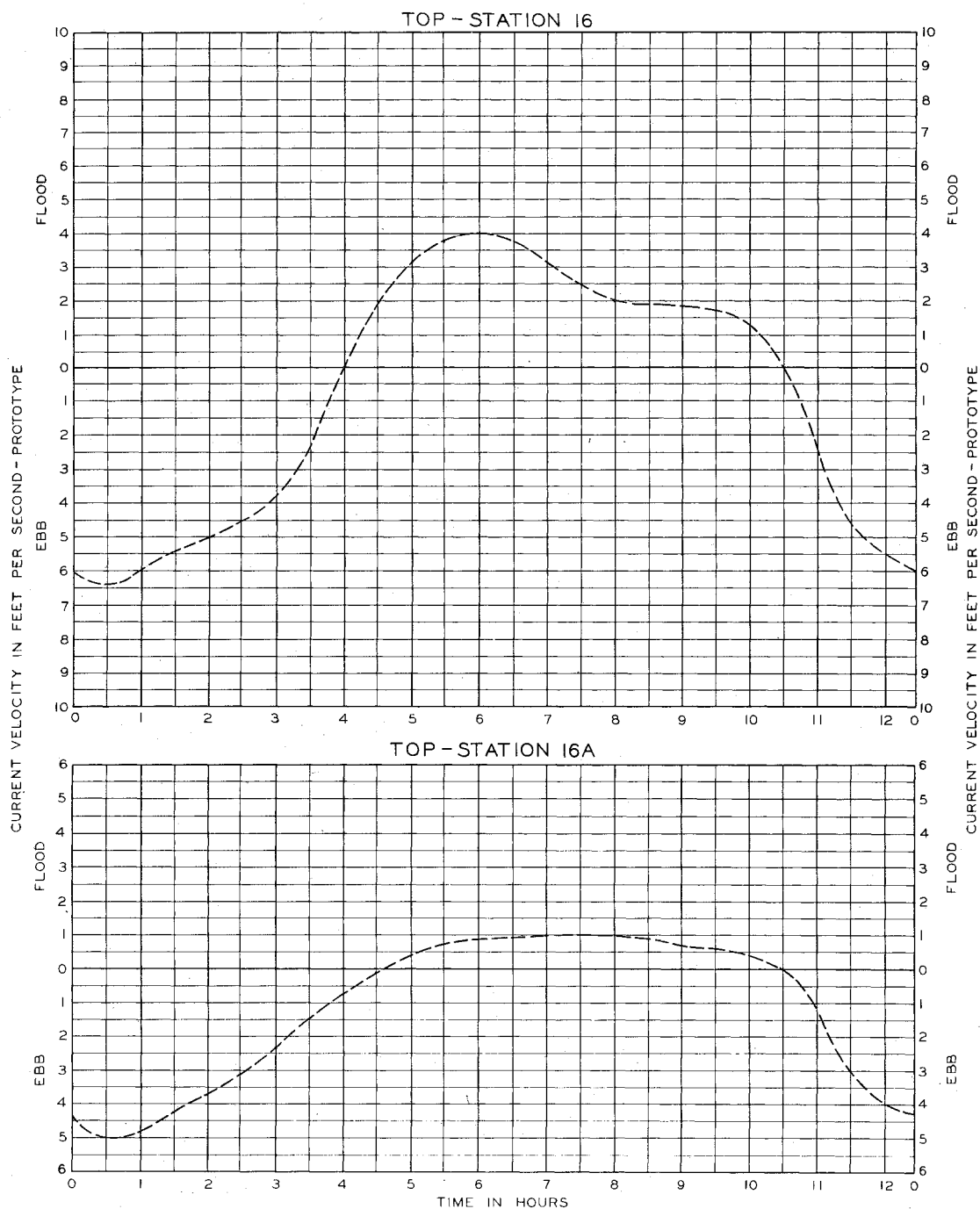
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN C-7 STATION 14

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

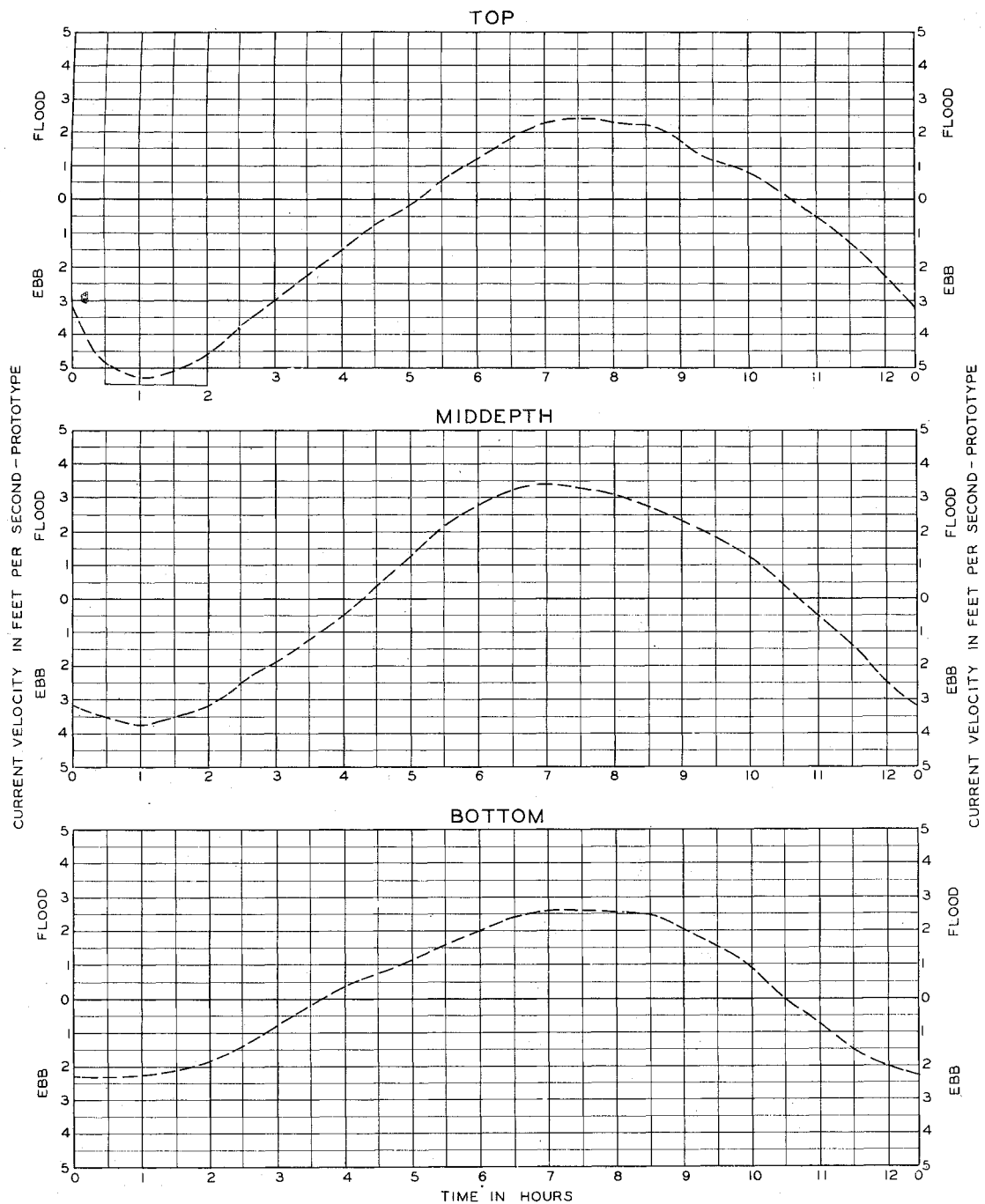
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT  
OF MAYPORT MERIDIAN.

VELOCITY CURVES  
PLAN C-7



**TEST DATA**

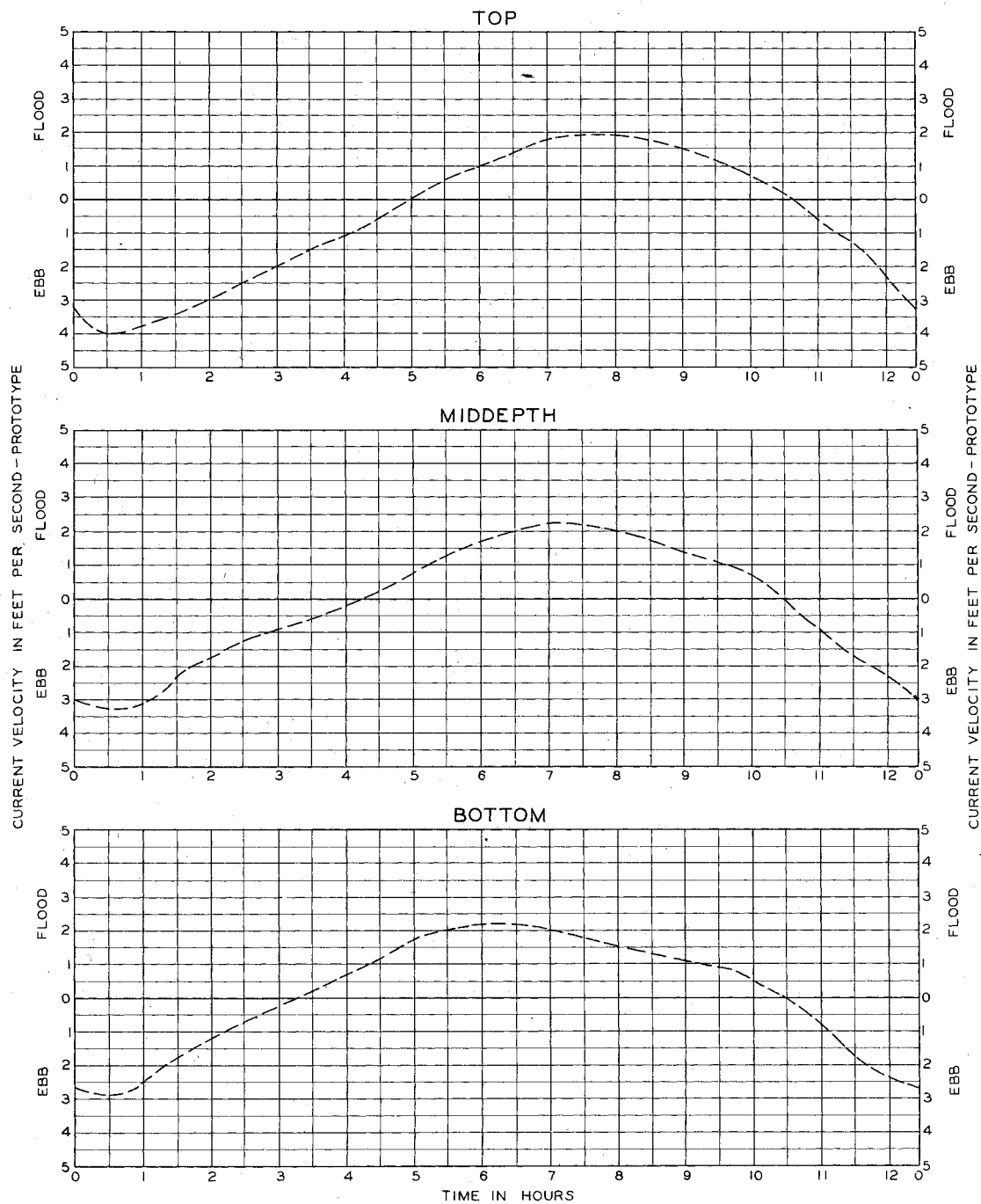
RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

**LEGEND**

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

**VELOCITY CURVES  
PLAN D-1  
STATION 17**

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.



#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

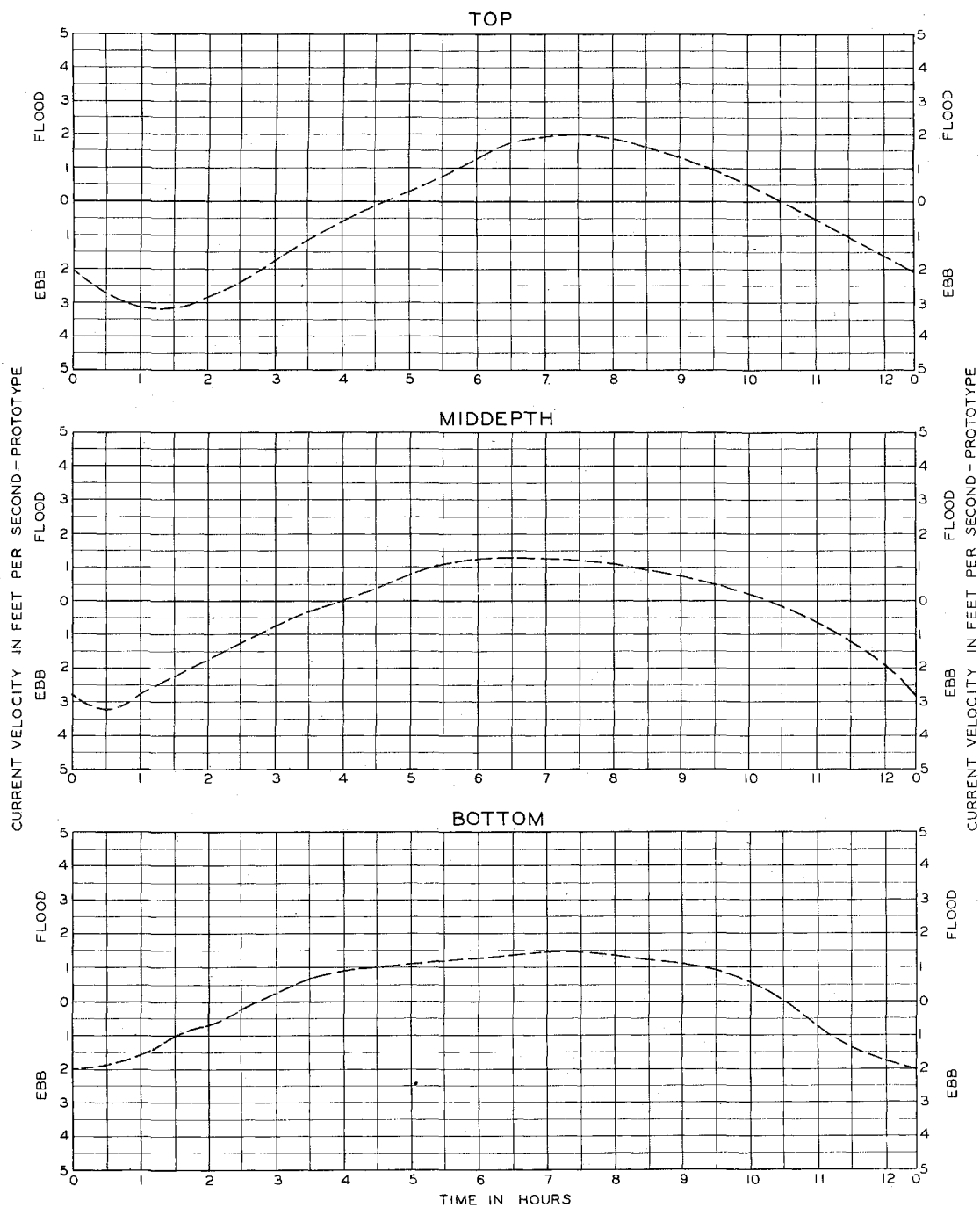
#### LEGEND

———— BASE TEST VELOCITY CURVES  
----- PLAN VELOCITY CURVES

VELOCITY CURVES  
PLAN D-1  
STATION 17A

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.





#### TEST DATA

RIVER DISCHARGE 4,000 CFS  
MEAN TIDE

#### LEGEND

— BASE TEST VELOCITY CURVES  
- - - PLAN VELOCITY CURVES

### VELOCITY CURVES PLAN D-1 STATION 17B

TIME IS EXPRESSED IN HOURS AFTER MOON'S TRANSIT OF  
MAYPORT MERIDIAN.

## APPENDIX

## APPENDIX

MODEL STUDY OF PLANS FOR PREVENTION OF POLLUTION IN  
THE ST. JOHNS RIVER AT JACKSONVILLE, FLORIDA

Introduction

1. The hydraulic model study herein reported was performed at the Waterways Experiment Station for the City of Jacksonville, Florida, under authority granted by the Chief of Engineers in first indorsement dated 13 August 1946 to letter dated 3 August 1946 from the City Engineer, City of Jacksonville, Florida. The study was conducted during the month of November 1946, and a detailed report thereon was submitted to the City of Jacksonville in February 1947. This appendix is identical to that report except that certain descriptive matter which has been presented in the main body of this report is not repeated herein.

2. The problem with which the model study was concerned was the possibility of a polluted condition along the west bank of the St. Johns River between the mouth of Ortega River and the railway bridge at the City of Jacksonville, where a number of the city's largest sewer outfalls are located. While there is no serious pollution problem in that area at present, the tidal currents along the west bank of the river are believed to be of insufficient magnitude to eliminate the possibility of eventual pollution.

3. It was the purpose of the model study to ascertain what installations would be necessary or desirable to increase the velocity of the tidal currents and align them closely enough to the west bank of the

St. Johns River in the problem area so that the sewage would either be transported to the main channel of the river, and eventually carried to the sea, or would be sufficiently diluted to be harmless.

4. For the tests reported in this appendix, a fresh-water discharge of 12,000 cfs was reproduced. Current velocities were measured by timing the travel of a float (0.035 ft in diameter, 0.035 ft long, floated about three-fourths submerged) over a measured range; velocities were measured at 28 stations (see plate A2) for basic conditions and at stations 1-12 during tests of improvement plans. Current directions in the model were recorded by means of flow-pattern photographs, made by taking 6-second exposures of confetti moving on the water surface. Current velocity measurements are superimposed upon the same photographs, which thus provide a complete record of both current directions and velocities.

#### Proposed Improvement Plans

5. After structures of various types and lengths had been experimented with in the model, three structures were selected as indicating the highest degree of effectiveness toward solution of the pollution problem; therefore, these structures were subjected to actual testing in the model. The structures are described in discussions of individual tests, and are referred to hereinafter as plans 1, 2, and 3 (plate A1).

##### Plan 1

6. Description. Plan 1 consisted of a training wall 2020 ft long, roughly parallel to the west bank of the St. Johns River and curved at the point where it entered the main channel of the river, so as to

deflect a portion of the flood current from the main channel into the area subject to pollution.

7. Results. The effects of plan 1 on current directions and velocities over the problem area can be determined by comparing photographs A1-A3 (base test) with photographs A4-A6 (plan 1). The most significant effects of plan 1 on existing conditions were: (a) the duration of flood currents along the west bank of the river was increased by approximately 2 to 3 hr; (b) in the area between the navigation channel and the west bank of the river the extensive eddies which are prevalent during the latter part of the flood period under existing conditions were eliminated by the plan; (c) under existing conditions, neither flood nor ebb currents follow the alignment of the west bank of the river between Stockton St. and Seminole Road, due to the depression in the general alignment of the west bank in that area; however, installation of plan 1 in the model completely corrected this condition, in that both flood and ebb currents followed closely the alignment of the west bank from the east end of the plan-1 structure to the general vicinity of Edgewood Ave.; (d) there were general increases in velocities of both flood and ebb currents between the plan-1 structure and the west bank of the river, these increases extending, in some instances, southwesterly to the general vicinity of Donald St.; and (e) the general changes in flow conditions along the west bank of the river caused by plan 1 effected a lag of approximately 2 hr in the times of flood and ebb tides in Ortega River.

#### Plan 2

8. Description. Plan 2 consisted of a straight, 3500-ft-long training wall placed off Sadler Point at an angle so as to intercept a

portion of the ebb current in the main channel of the St. Johns River and deflect it across the mouth of Ortega River into the area subject to pollution.

9. Results. The effects of plan 2 on current directions and velocities over the problem area are shown by comparison of photographs A1-A3 with photographs A7-A9. These effects were: (a) the plan effected some increases in velocities of ebb currents along the west bank of the river between Shadowlawn St. and Donald St., and the alignments of ebb currents throughout that area were improved somewhat; (b) during a part of the flood period the plan caused the currents to swing slightly away from the west bank of the river in the general vicinity of Donald St.; (c) large eddies were formed on the downstream side of the training wall during the ebb period and on the upstream side during the flood period; and (d) there were considerable changes in the patterns of flood and ebb currents in the mouth of Ortega River; however, neither the durations nor velocities of these currents were affected appreciably.

#### Plan 2A

10. Description. Plan 2A was a combination of the plan-1 and plan-2 structures.

11. Results. Photographs A10-A12 illustrate the following effects of plan 2A on current directions and velocities over the problem area: (a) the duration of flood currents along the west bank of the river was increased by approximately 2 hr and the velocities of these currents were increased substantially; (b) the duration of ebb currents along the west bank was decreased by approximately 2 hr; (c) the eddies which existed between the navigation channel and the west bank of the river under existing conditions

were eliminated; (d) between Stockton St. and Seminole Road the alignments of flood currents followed closely the general bank line, but the alignments of ebb currents in that area, while indicating some improvement over existing conditions, were not so good as for the test of plan 1; (e) the alignments of ebb currents were improved somewhat between Shadowlawn St. and Donald St.; (f) large eddies were formed on the downstream side of the plan-2 structure during the ebb period and on the upstream side during the flood period; and (g) during a part of the flood period, the currents veered away from the west bank in the general vicinity of Donald St.

### Plan 3

12. Description. Plan 3 comprised a 900-ft jetty at the mouth of Ortega River, placed in a position roughly perpendicular to the channel of that tributary. The purposes of this jetty were to contract the channel of Ortega River and thus increase the current velocity therein, and also to direct the alignments of flood and ebb currents of Ortega River nearer to the large sewer outfall located immediately downstream from the mouth of Ortega River.

13. Results. The only effects of plan 3 on current directions and velocities over the problem area, as shown by comparing photographs A1-A3 with photographs A13-A15, were slight increases in flood and ebb current velocities in the mouth of Ortega River, and a slight shifting of the current alignments, particularly during ebb, toward the west bank of the St. Johns River. This shift in current alignment was entirely local, and would affect only that portion of the problem area lying between Shadowlawn St. and a point on the west bank approximately opposite

the plan-3 jetty.

#### Plan 3A

14. Description. Plan 3A was a combination of the plan-1, plan-2, and plan-3 structures.

15. Results. The effects of plan 3A on current directions and velocities over the problem area can be determined by comparing photographs A1-A3 with photographs A16-A18. The effects of plan 3A on existing conditions were, for all practical purposes, the same as the effects of plan 2A. The addition of the plan-3 structure appeared to have improved somewhat the alignments of flood and ebb currents between Shadowlawn St. and the mouth of Ortega River, and flood and ebb current velocities were increased slightly in the mouth of Ortega River; however, these slight variations from the results of plan 2A were entirely local, being confined to the general vicinity of the mouth of Ortega River.

#### Plan 3B

16. Description. Plan 3B was a combination of the plan-1 and plan-3 structures.

17. Results. The effects of plan 3B (see photographs A19-A21) on existing conditions were about the same as those of plan 1, described previously, with the one exception that alignments of flood and ebb currents were improved somewhat between the mouth of Ortega River and the general vicinity of Shadowlawn St.

#### Plan 3C

18. Description. Plan 3C was a combination of the plan-2 and plan-3 structures.



19. Results. The effects of plan 3C (shown by photographs 'A22-A24) on existing current directions and velocities were about the same as for the test of plan 2 with the exception that alignments of flood and ebb currents were improved somewhat between Shadowlawn St. and the mouth of Oretga River.

#### Discussion of Results

20. In order to understand clearly the advantages and disadvantages of the proposed plans of improvement, the effects of each of the three basic plans (plans 1, 2, and 3) must be considered singly and in combination. Plan 1 appears to be much more effective than either plan 2 or 3 in the solution of the problem, in that it improved both the alignments and velocities of flood and ebb currents along the west bank of the river from the east end of the plan-1 structure to the general vicinity of Edgewood Ave. Plan 1 appeared to have very little, if any, beneficial effect in that portion of the problem area lying between Edgewood Ave. and the mouth of Ortega River; however, it had no apparent detrimental effects in that area. Plan 1 was also effective in eliminating the large eddies which formed, during the latter part of flood tide, in the area between the navigation channel and the west bank of the river. It is not known whether elimination of these eddies would prove beneficial to the over-all problem, due to the fact that the eddies were well off-shore; however, it is believed that elimination of the eddies would shorten the time required for the eventual transportation of sewage by tidal currents from sewer outfalls to the main channel of the river.

21. The beneficial effects of plan 2, when tested alone, appeared

to be limited to improvements in alignments and velocities of ebb currents in that portion of the problem area between Shadowlawn St. and Edgewood Ave. This plan caused the flood currents to break away more sharply from the bank line in the vicinity of Edgewood Ave. than the break which occurs for existing conditions. Furthermore, large eddies were formed upstream from the plan-2 structure during flood tide, and downstream from the structure during ebb. The effects of these eddies are not known definitely; however, it is believed that sewage caught in such eddies would remain therein through at least one complete phase of the tide, and thus would be retarded in its movement out into the river proper.

22. The effects of plan 3 alone appear to be entirely local, being confined to the west bank of the river between the mouth of Ortega River and Shadowlawn St.; however, it is believed that some benefits would be effected in that vicinity. For existing conditions, flood currents into Ortega River pass directly over the end of one of the large sewer outfalls, while ebb currents from the river appear to hug the east bank of Ortega River and then follow closely the bank line around Sadler Point. The plan-3 structure caused the main ebb currents to pass directly over the sewer outfall, as well as the flood currents, which should produce better circulation of water, and thus greater dilution of the sewage, at the end of the outfall.

23. The over-all effects of the plan-1 and plan-2 structures, when tested in combination (plan 2A), do not appear to be as good as were provided by the plan-1 structure alone. There appears to be some improvement over plan 1 in the alignments and velocities of ebb currents

between Shadowlawn St. and Edgewood Ave.; however, between Edgewood Ave. and the east end of the plan-1 structure, flood and ebb current alignments and velocities for plan 1 were considerably better than when plan 1 and plan 2 were tested together (plan 2A).

24. The further addition of the plan-3 structure to the plan-1 and plan-2 structures (plan 3A) effected local improvements in the alignments of flood and ebb currents between Shadowlawn St. and the mouth of Ortega River; however, the addition of the plan-3 structure effected no apparent benefits over the remainder of the problem area.

25. The effects of plan 2 and plan 3, when tested in combination (plan 3C), indicated slight local improvements over the test of plan 2 alone in alignments of flood and ebb currents between Shadowlawn St. and the mouth of Ortega River; however, it is believed that these two plans in combination would effect but little benefit to that portion of the problem area lying north of Edgewood Ave.

26. The effects of plans 1 and 3, when tested in combination (plan 3B), indicated some improvement over the test of plan 1 alone, in that alignments of flood and ebb currents between Shadowlawn St. and the mouth of Ortega River were improved somewhat. Addition of the plan-3 structure appeared to have no detrimental effects upon the advantageous effects of the plan-1 structure when tested alone.

### Conclusions and Recommendations

#### Conclusions

27. It is the opinion of the Experiment Station that plan 1 would provide sufficient circulation by tidal currents to prevent pollution

over that portion of the problem area lying between the east end of the plan-1 structure and the general vicinity of Edgewood Ave. Two of the three large sewer outfalls shown on plate 2 lie within this area; therefore, the over-all problem should be improved considerably by this plan.

28. With respect to the third of the large sewer outfalls, that which enters the river immediately downstream from the mouth of Ortega River, it is doubtful if any of the plans tested would prevent pollution of the surrounding area by that outfall. Such improvements in alignments and velocities of ebb currents as were effected by plan 2 appear to take effect too far downstream from the sewer outfall to be of material benefit. The plan-3 structure provided better circulation of flood and ebb currents over the outfall than exist at present, but it is not known whether or not such an improvement in circulation in that locality would result in a lesser degree of pollution. Due to the fact that this outfall is located so far back in the lee of Sadler Point and therefore, so far removed from the normal alignments of flood and ebb currents in the main river, it is considered doubtful if an economical and effective plan, based on deflection of currents from the main river into the area subject to pollution, could be devised.

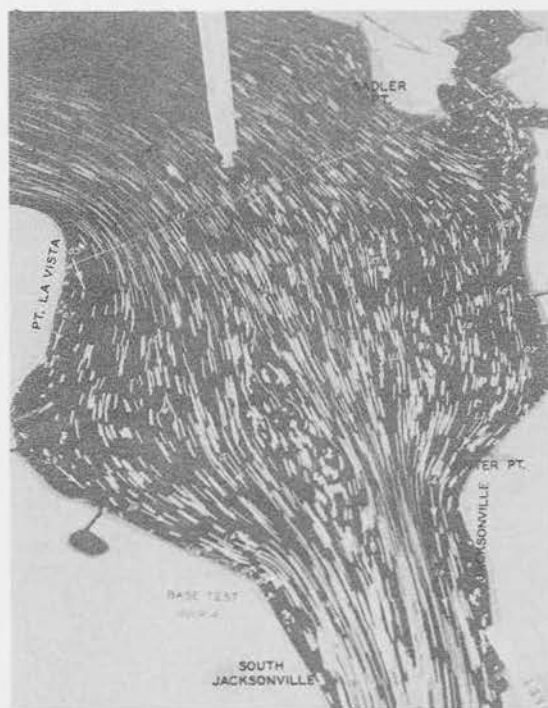
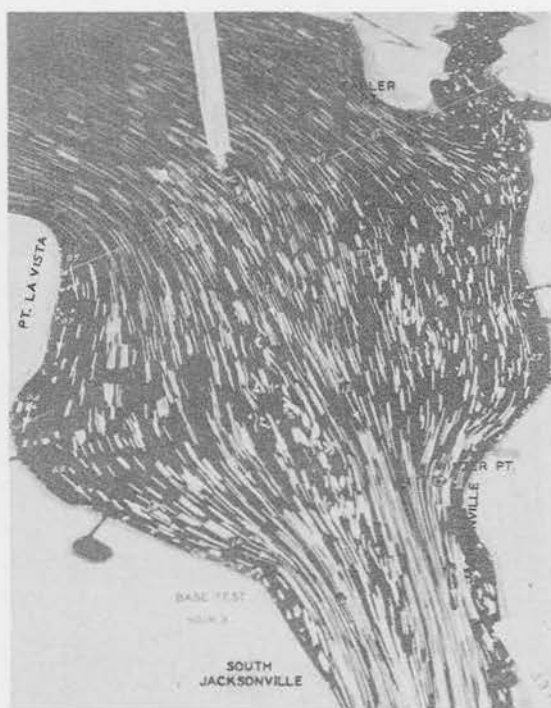
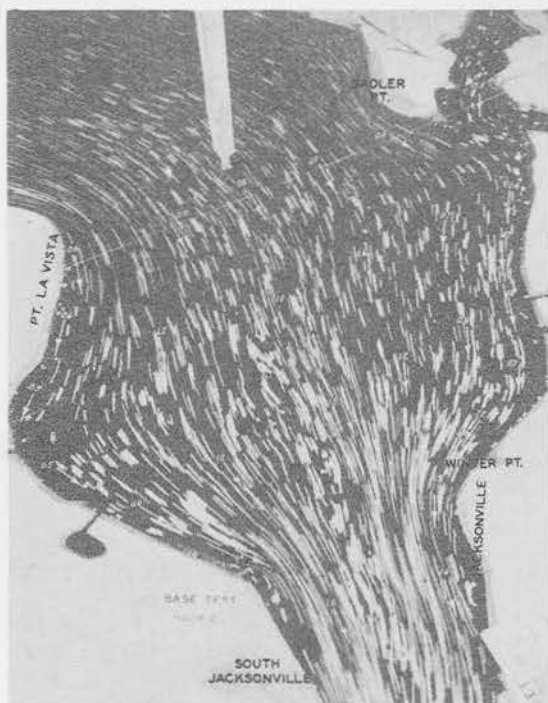
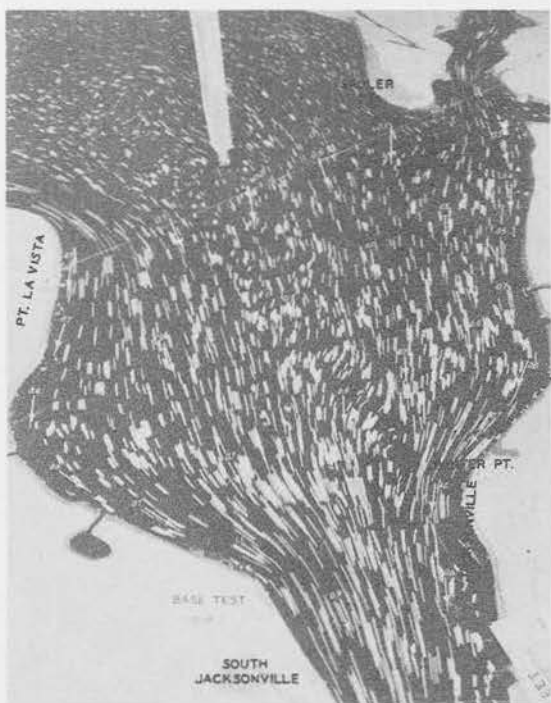
29. Proposed canal across Venitia Peninsula. During the course of the study, Mr. E. T. Owens raised the question of whether or not a canal across Venitia Peninsula (Sadler Point), connecting Ortega River with the St. Johns River, would be beneficial toward solution of the pollution problem below the mouth of Ortega River, and requested the Experiment Station to give its opinion as to the effects of such a canal. The proposed canal was not subjected to testing in the model; however,

water-surface elevations were obtained throughout a complete tidal cycle at the points in the St. Johns and Ortega Rivers which Mr. Owens pointed out as being the probable extremities of such a canal. These measurements showed that at no time during the tidal cycle did a head differential of greater than 0.1 ft (prototype) exist between the two points. Since flow through such a canal would depend directly upon a head differential between the two ends, it is believed that no beneficial effects would obtain from construction of such a canal.

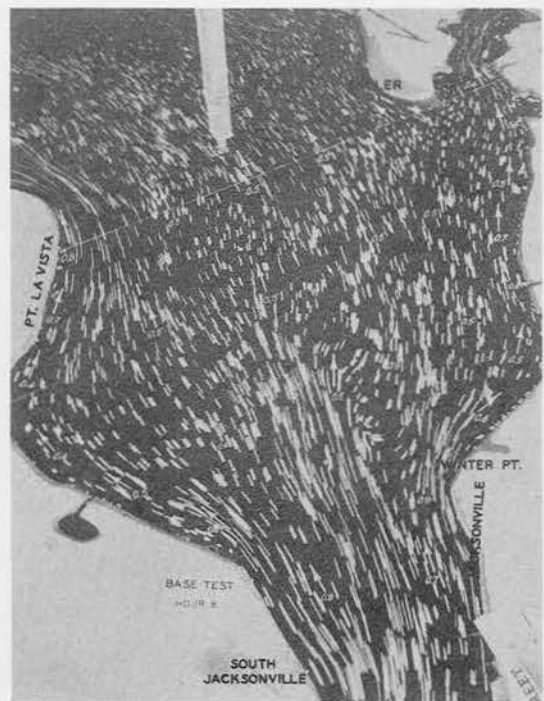
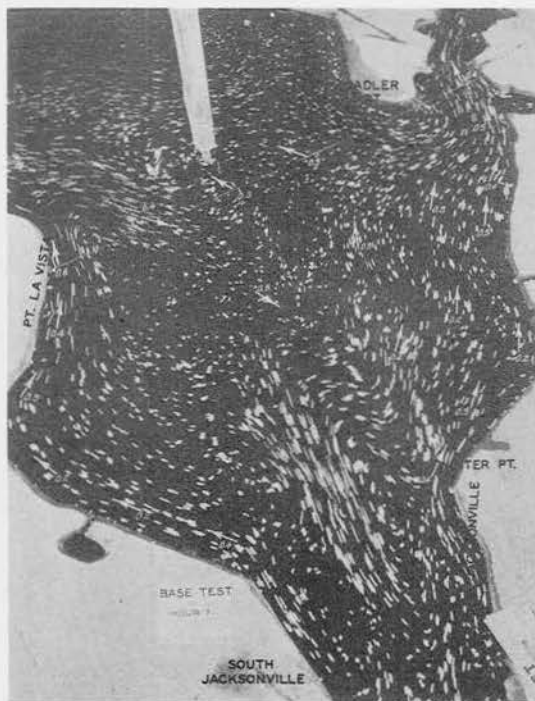
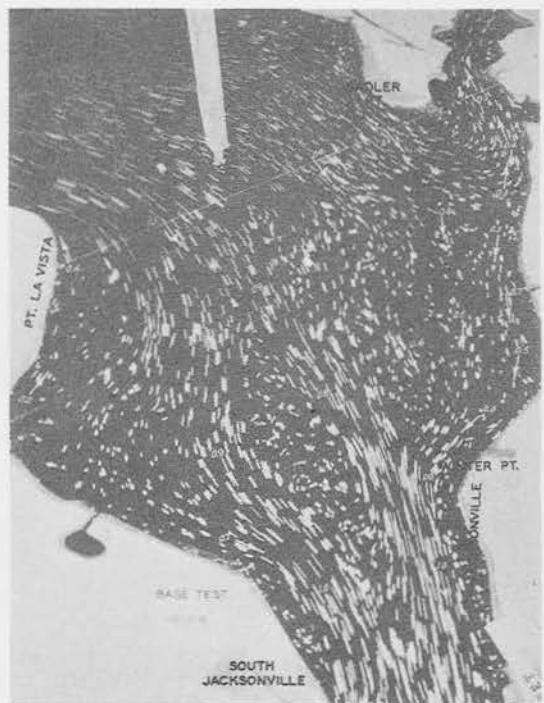
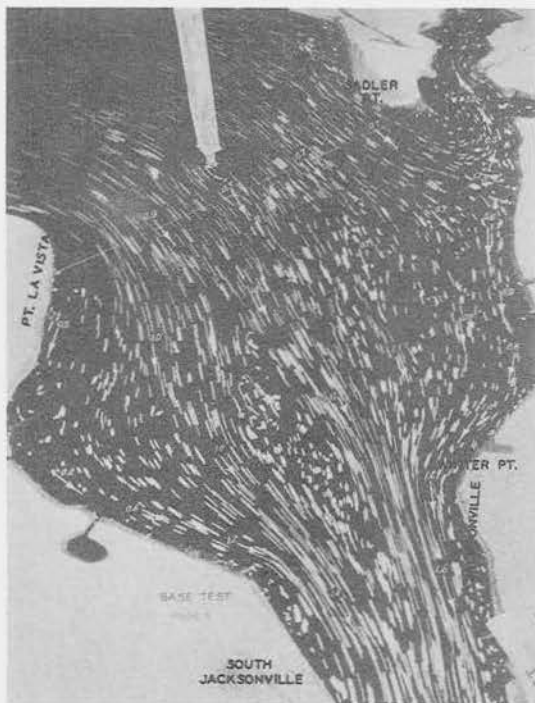
### Recommendations

30. The Experiment Station is not sufficiently cognizant of all phases of the problem to make definite recommendations for its complete solution. Furthermore, it is doubtful that any of the plans tested would prove to be completely effective in solution of the problem. It is the opinion of the Experiment Station, however, that a comprehensive plan for solution of the problem should be developed along the following general lines:

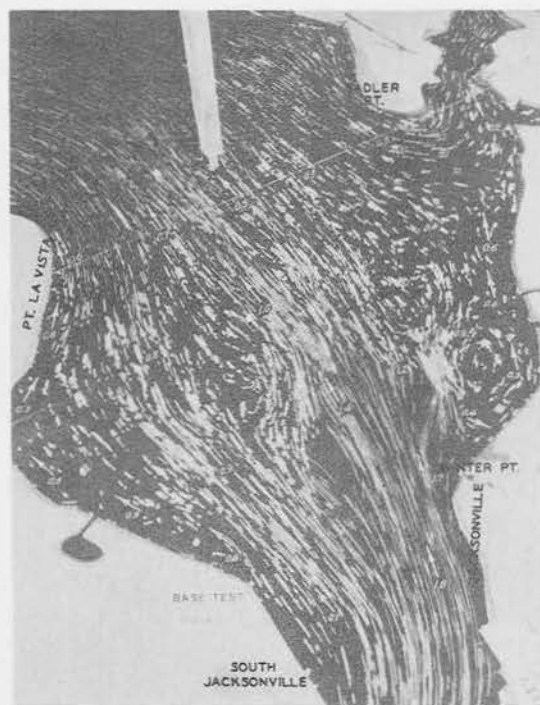
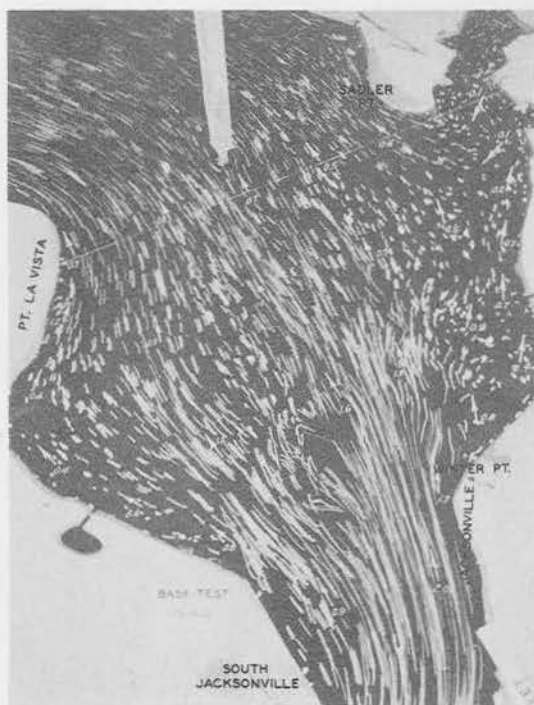
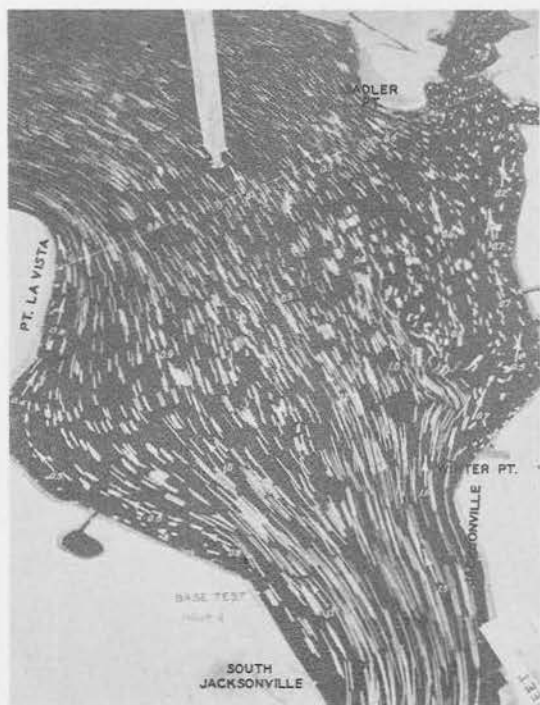
- a. Construct plan 1 in the prototype. Construction of this plan should improve considerably existing conditions in that portion of the problem area between the east end of the plan-1 structure and the general vicinity of Edgewood Ave.
- b. Following construction of plan 1, initiate a field survey to determine the effectiveness of the plan in reducing pollution over the problem area, particularly in that portion immediately downstream from the mouth of Ortega River.
- c. If pollution in and near the mouth of Ortega River is not improved, or becomes worse, after construction of plan 1, it is probable that plan 3, or some modification thereof, would prove to be of local benefit in that area.



PHOTOGRAPH A1

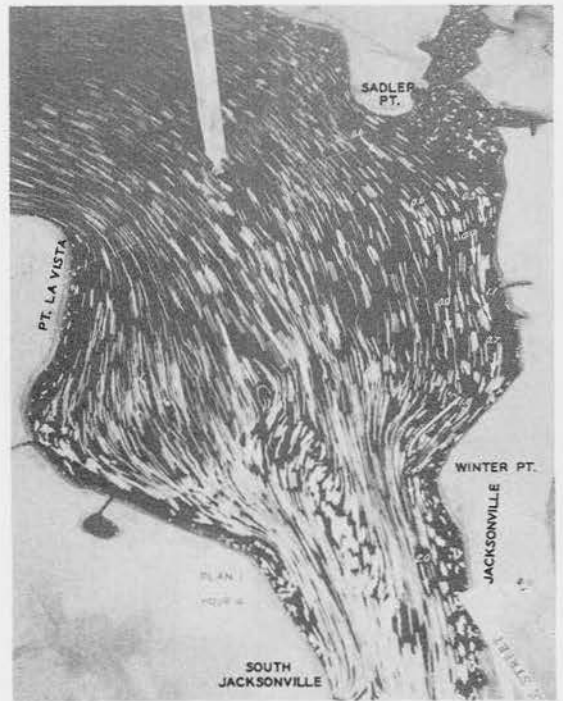
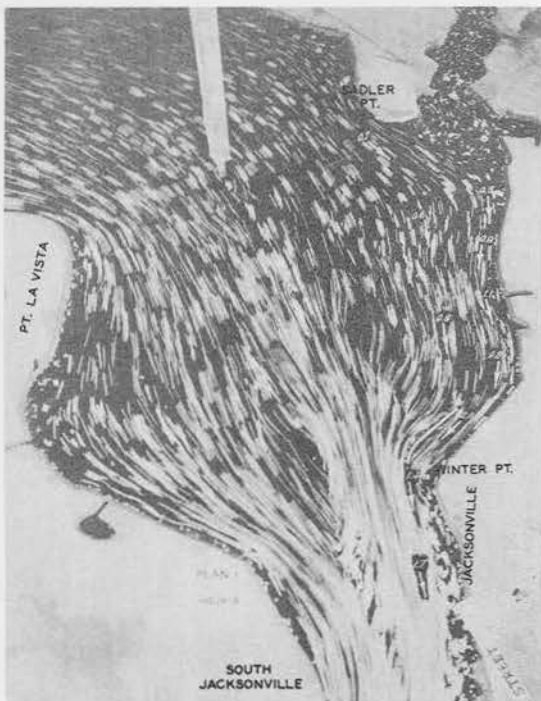
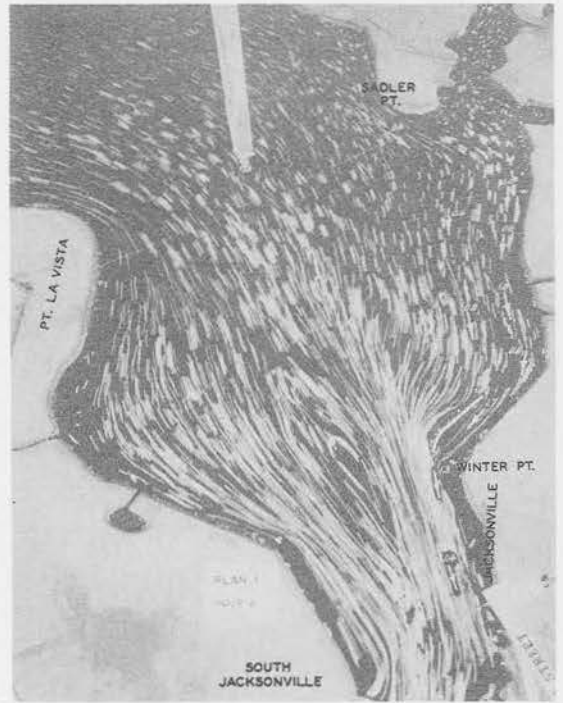
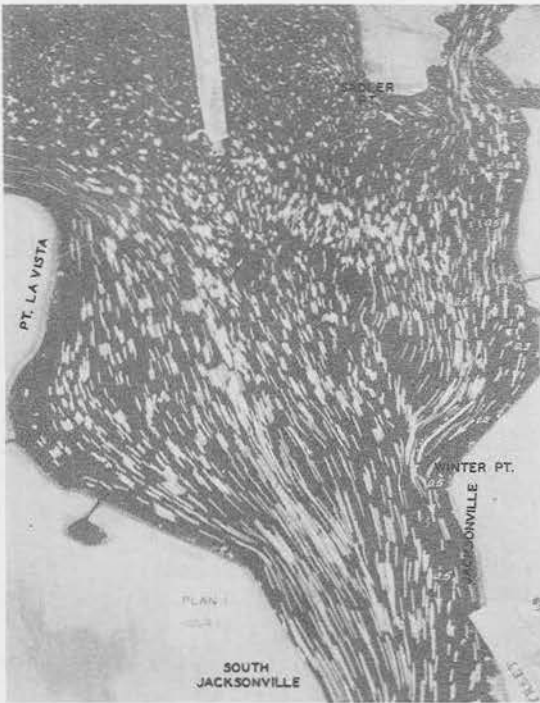


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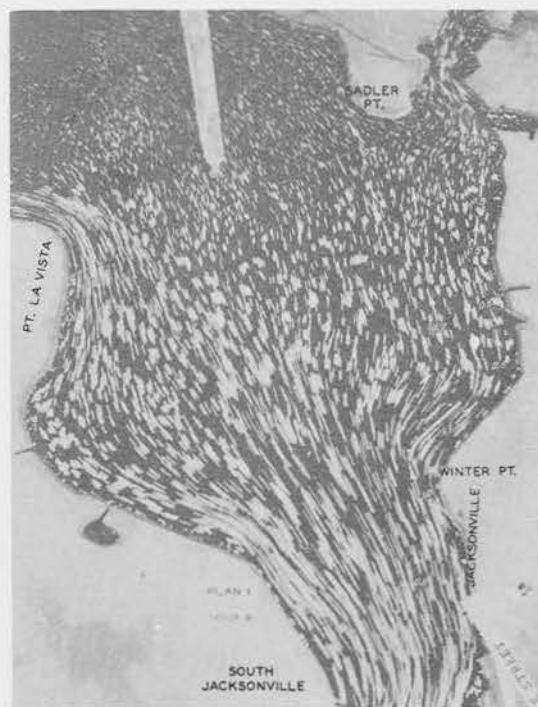
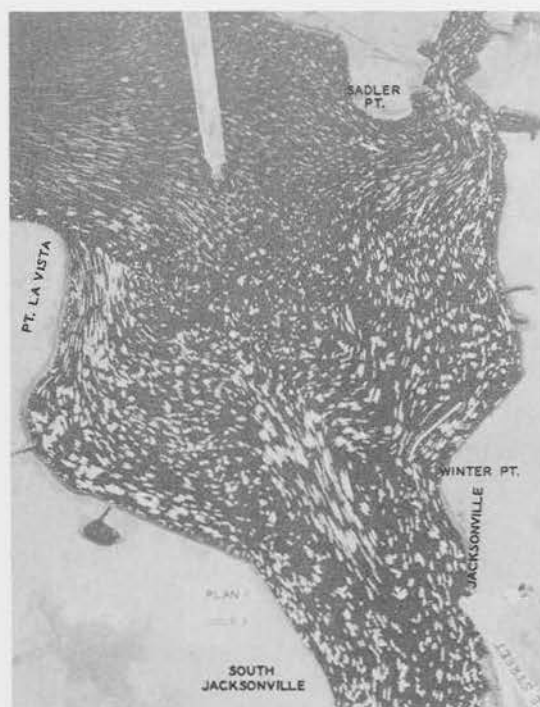
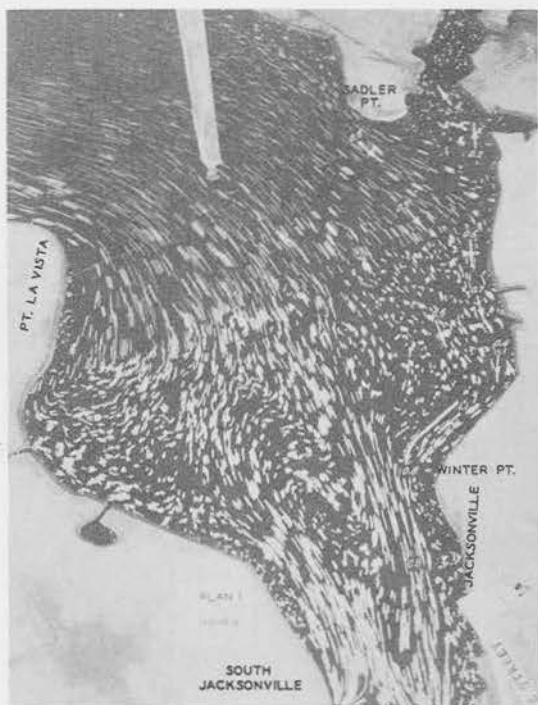
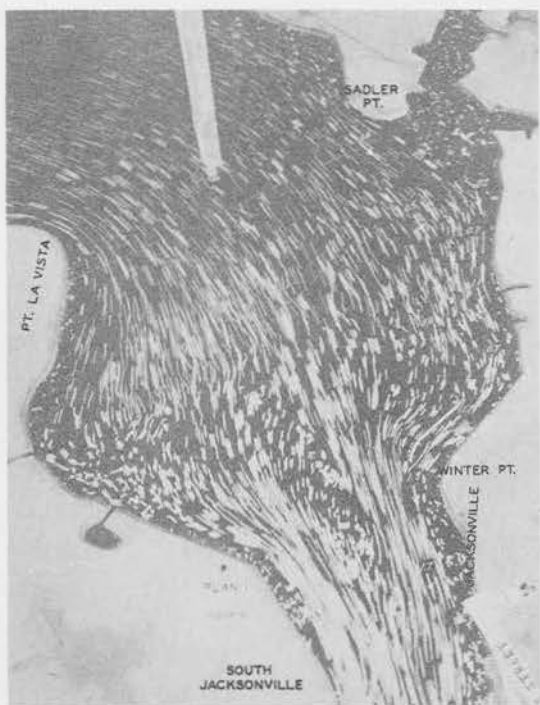


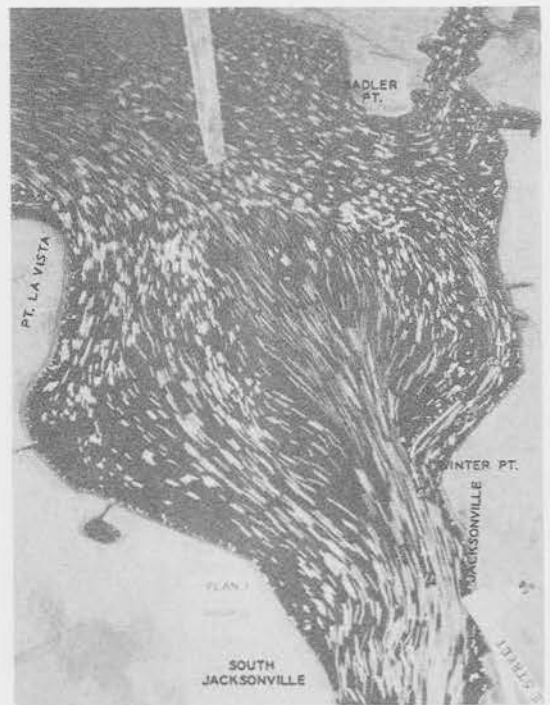
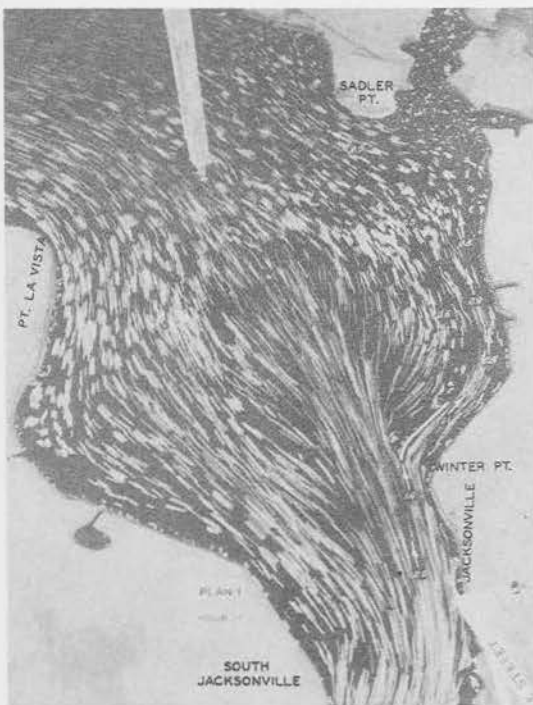
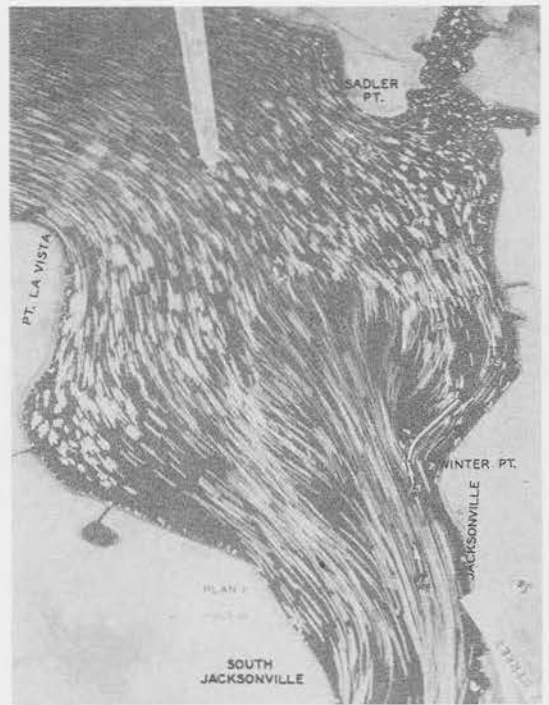
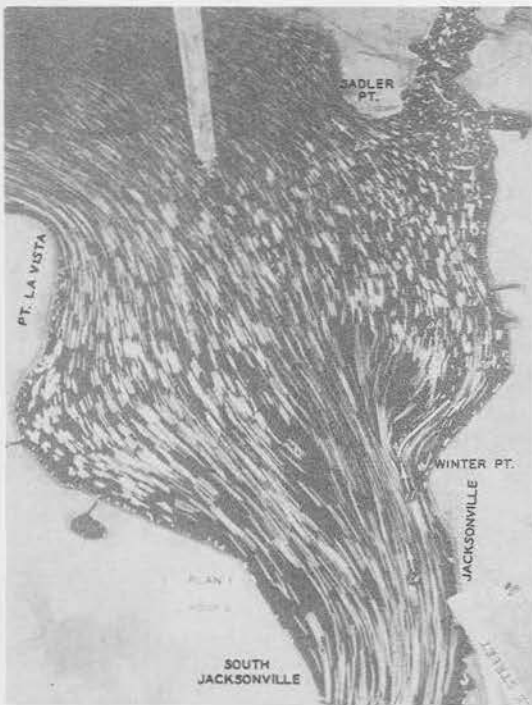
PHOTOGRAPH A3



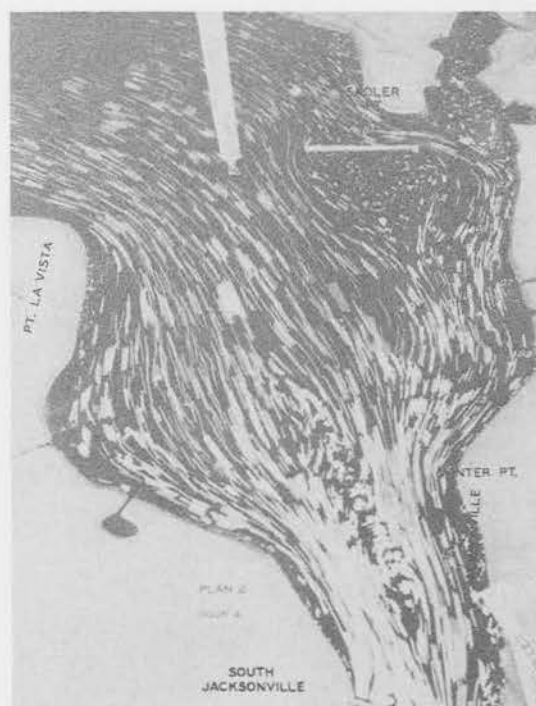


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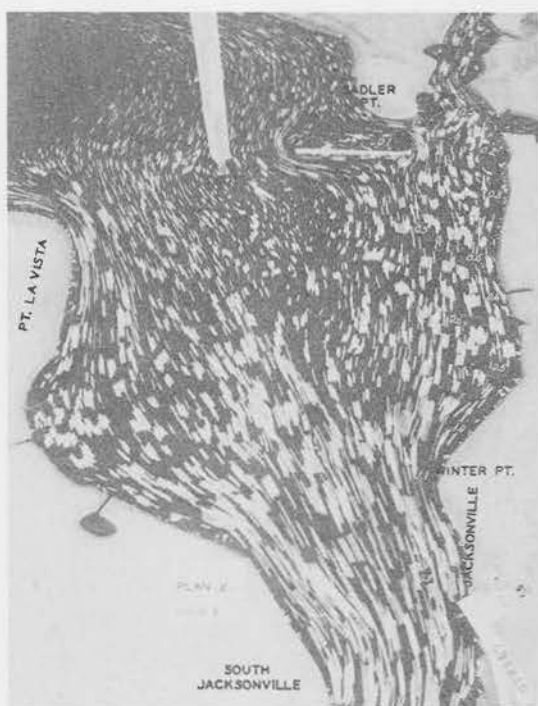
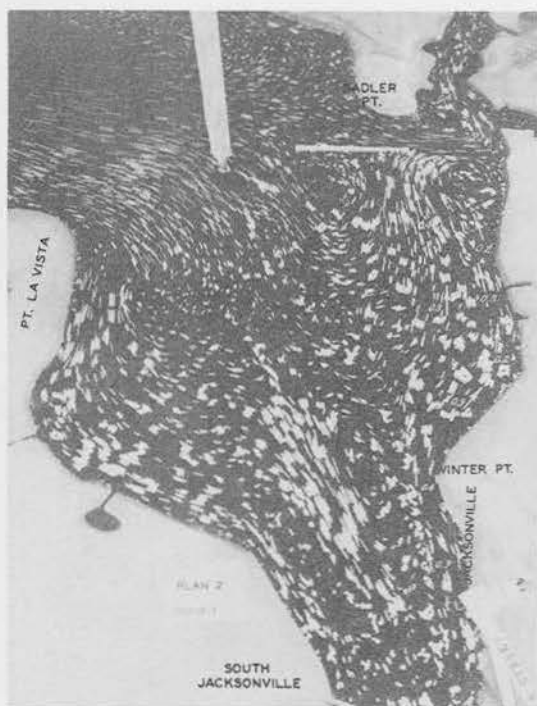
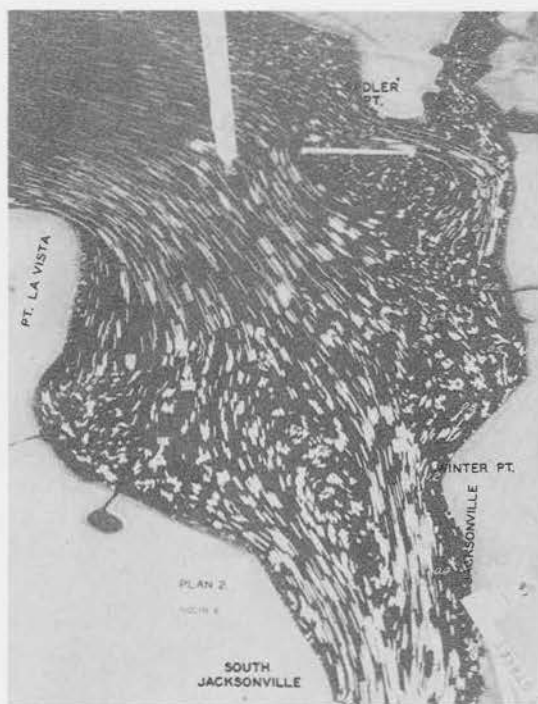
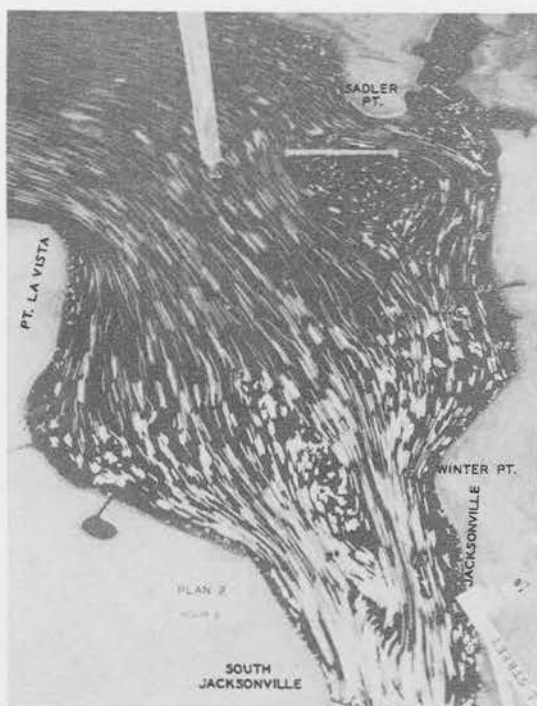




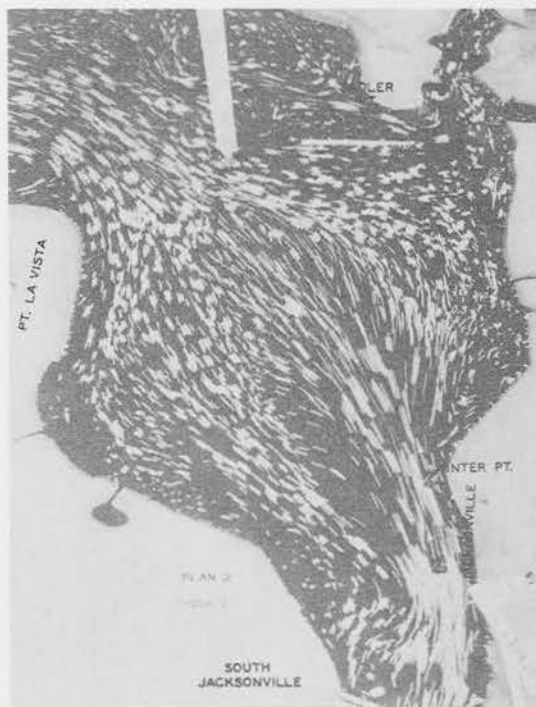
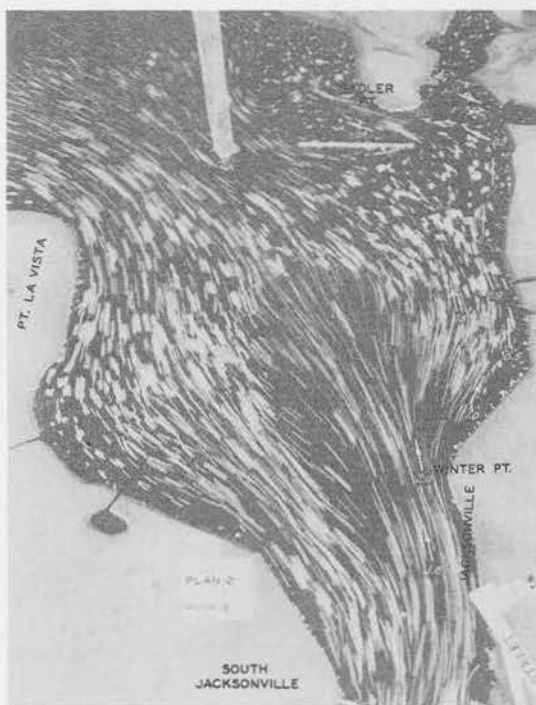
PHOTOGRAPH A6



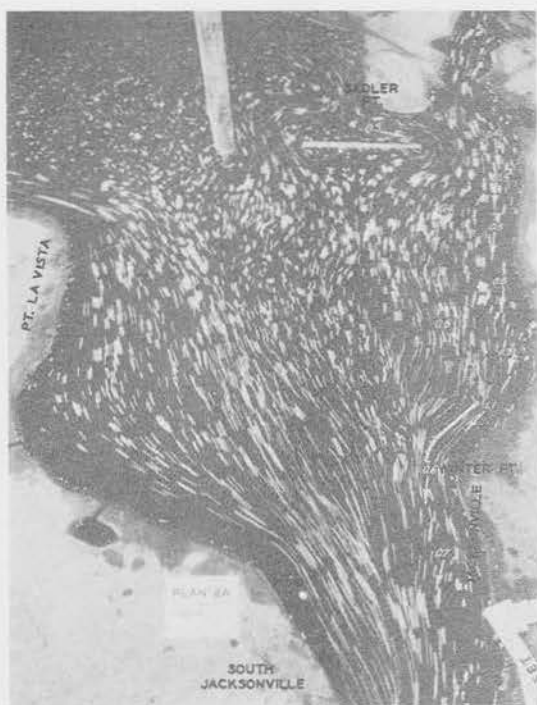




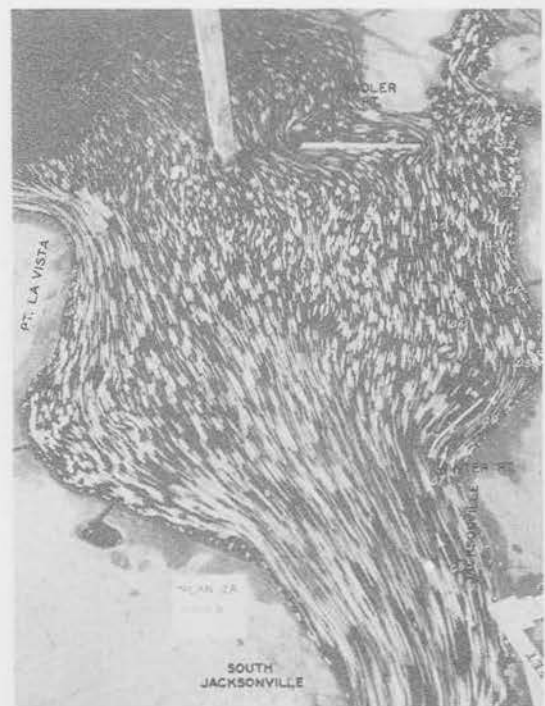
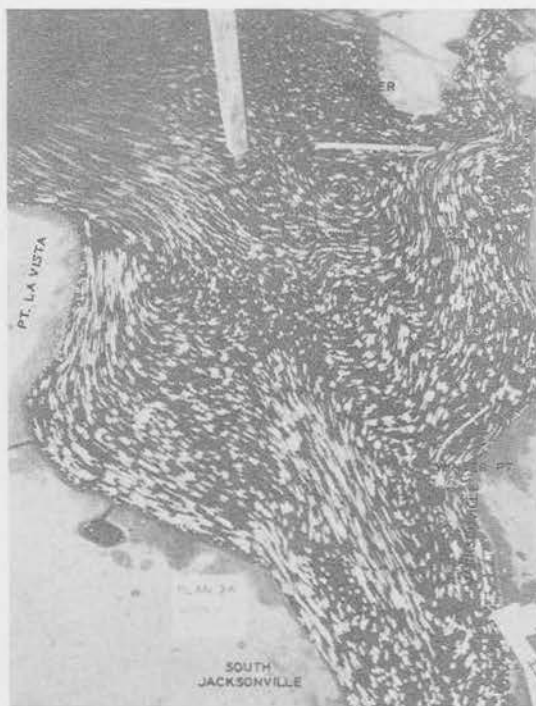
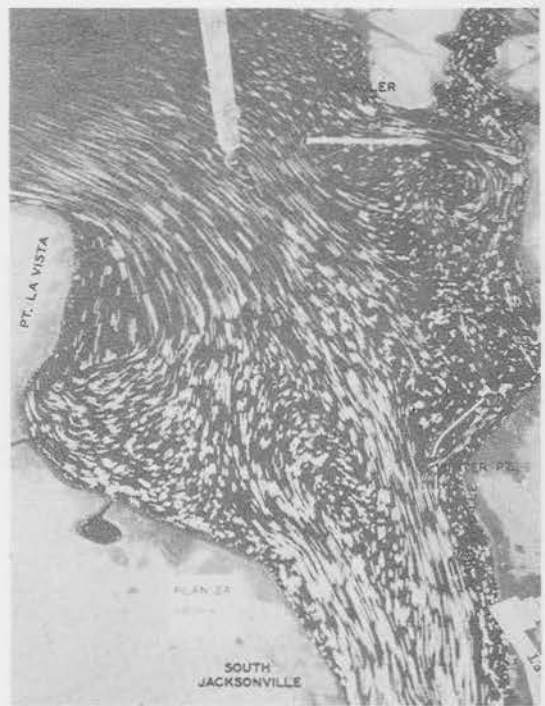
PHOTOGRAPH A8



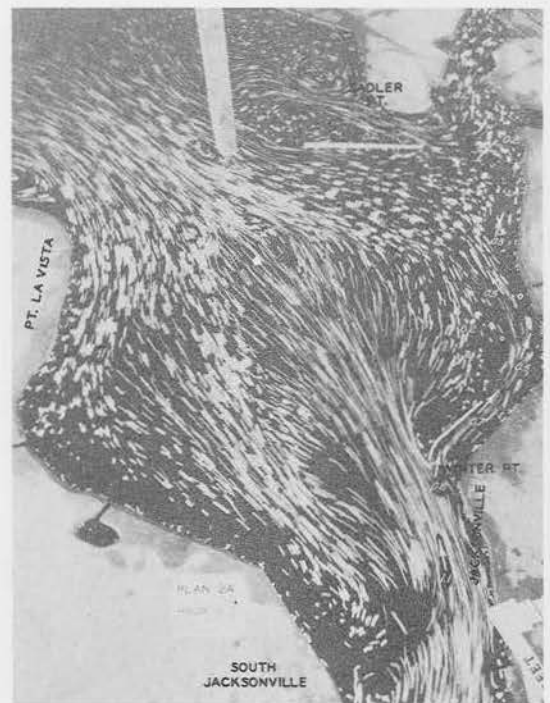
PHOTOGRAPH A9



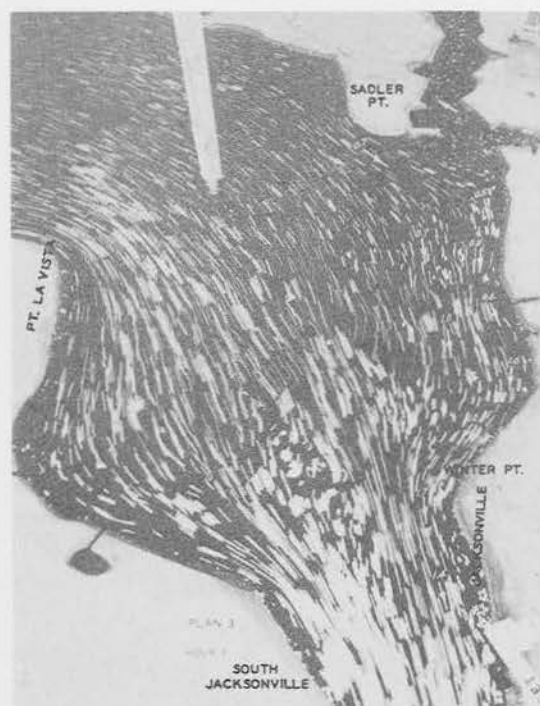
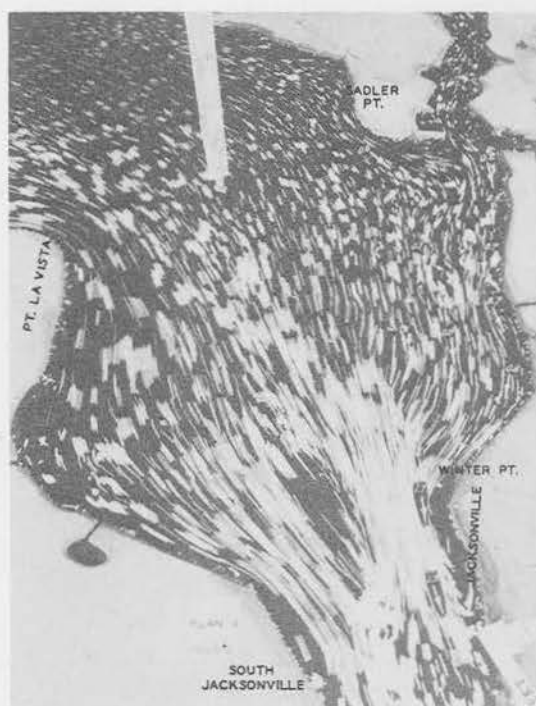
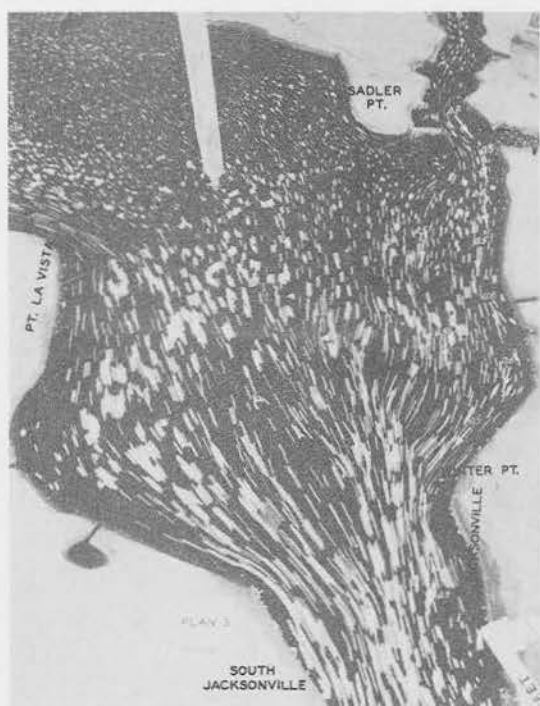
PHOTOGRAPH A10

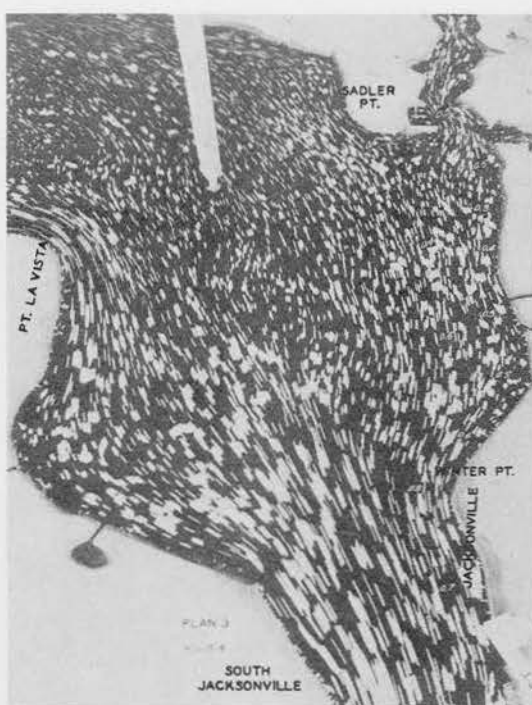
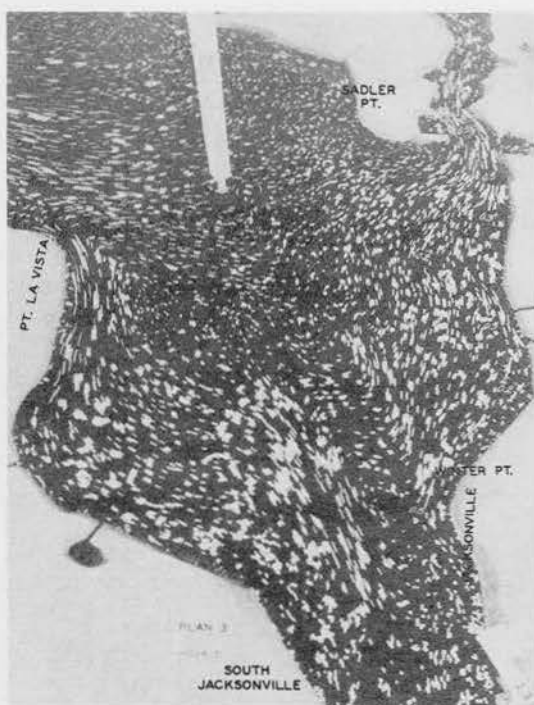
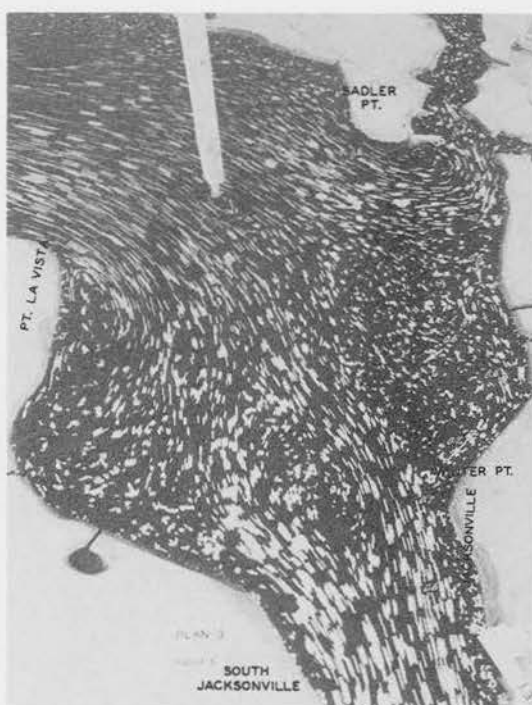


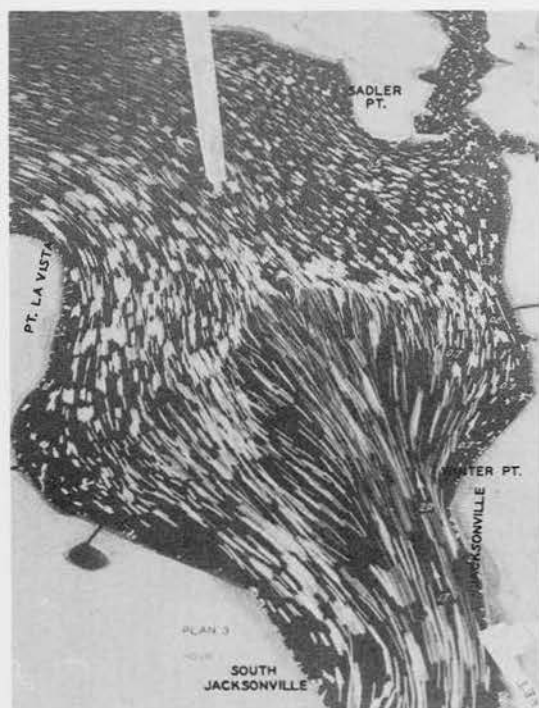
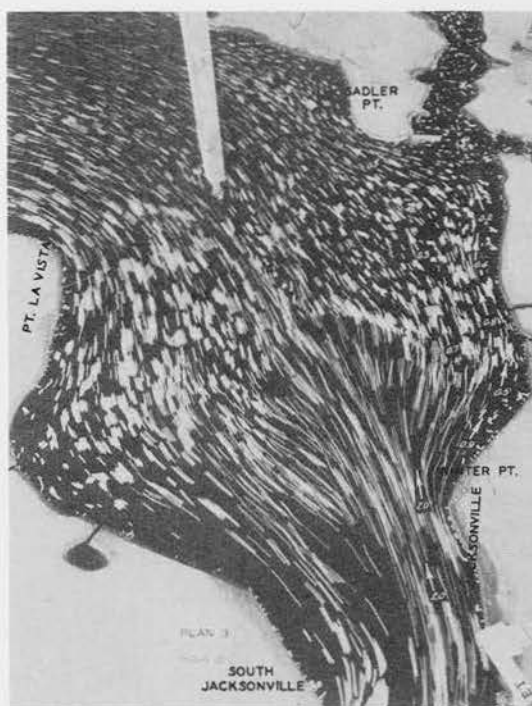
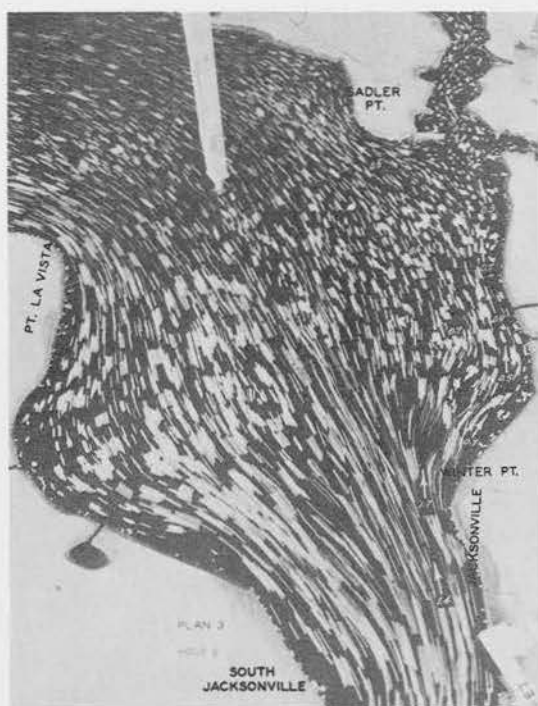




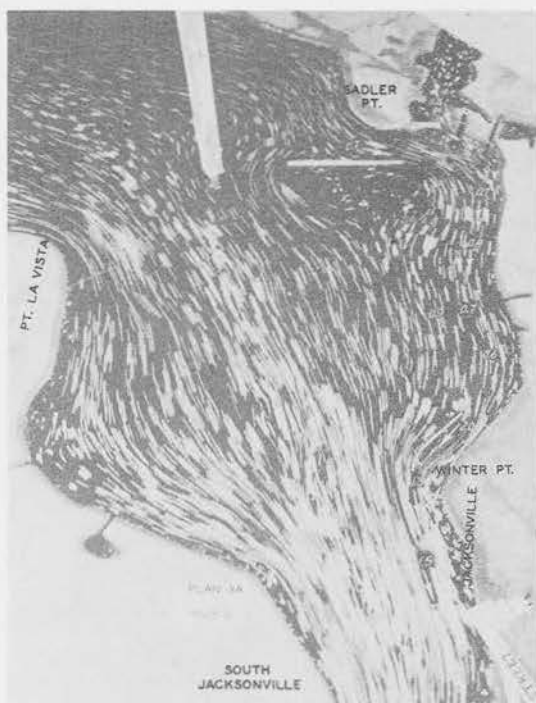
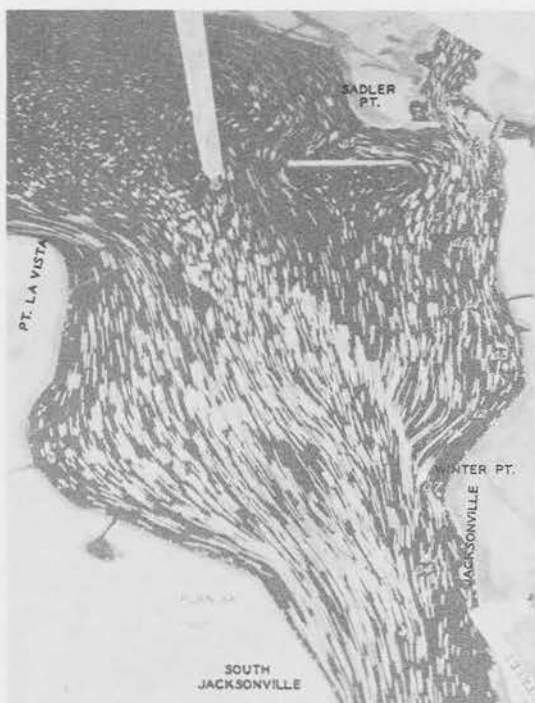
PHOTOGRAPH A12





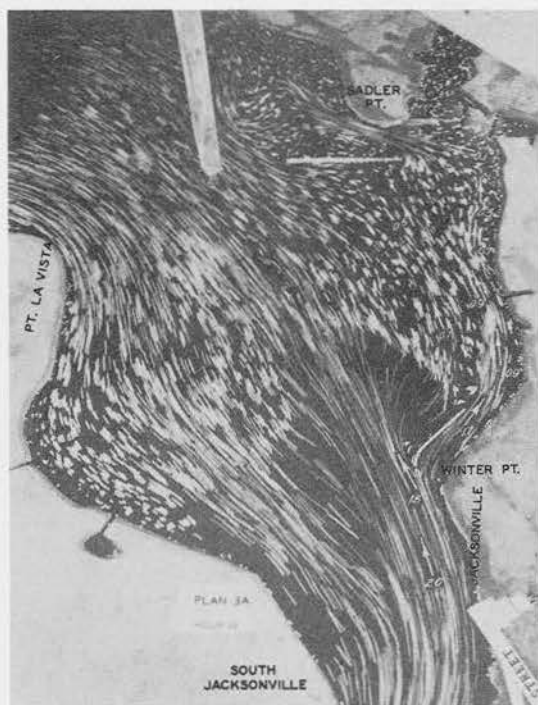
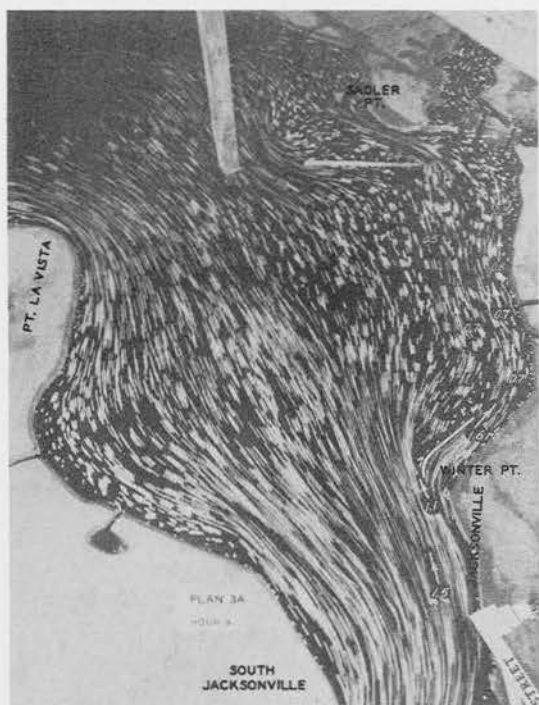




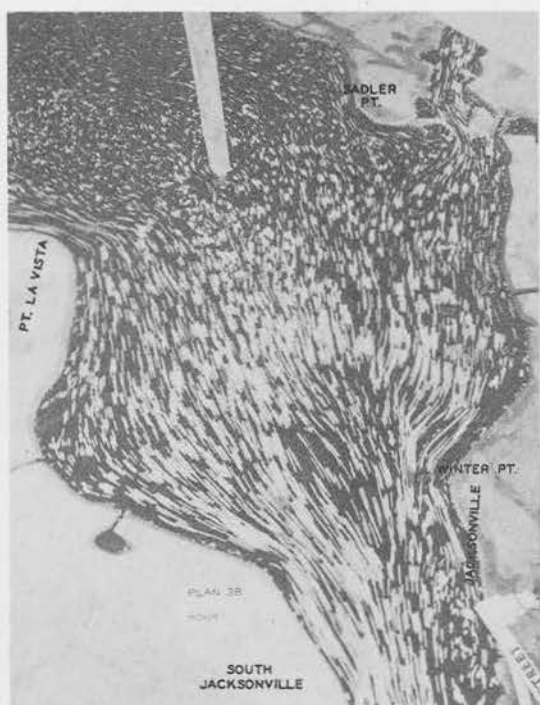


PHOTOGRAPH A16





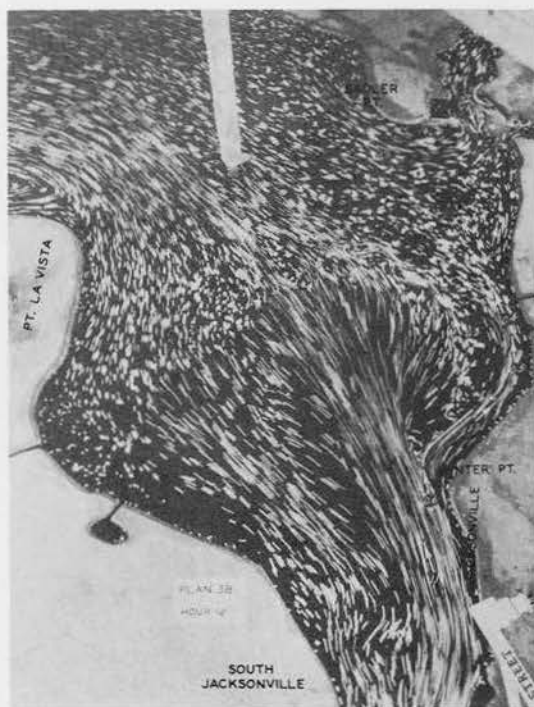
PHOTOGRAPH A18

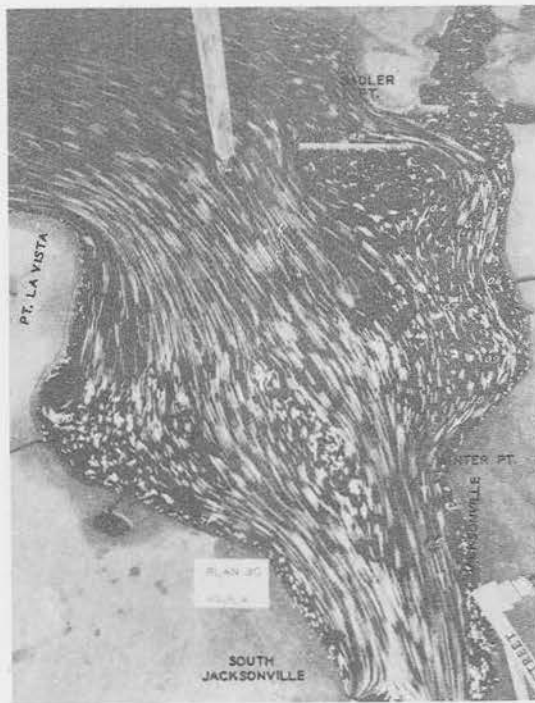


PHOTOGRAPH A19

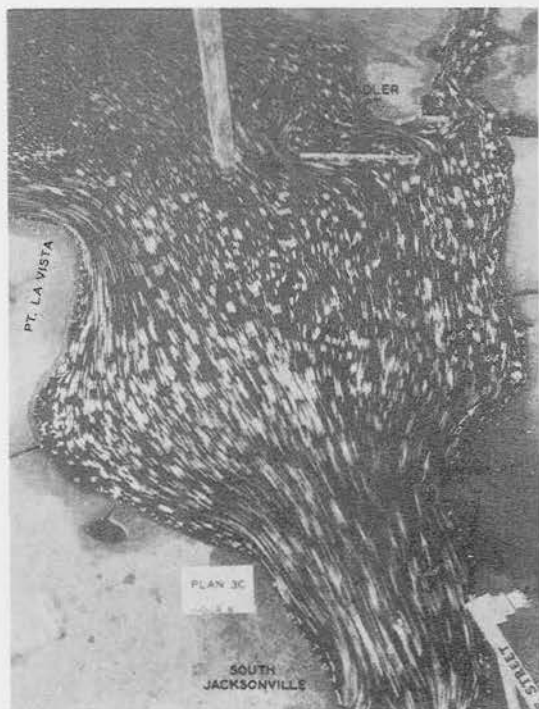
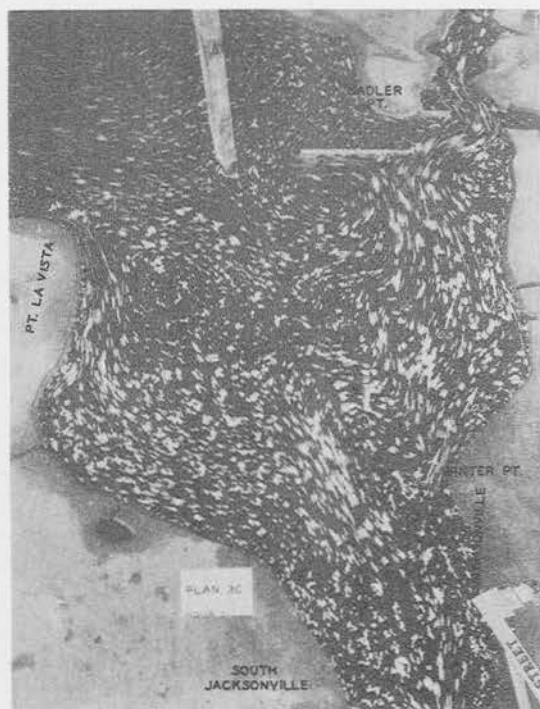
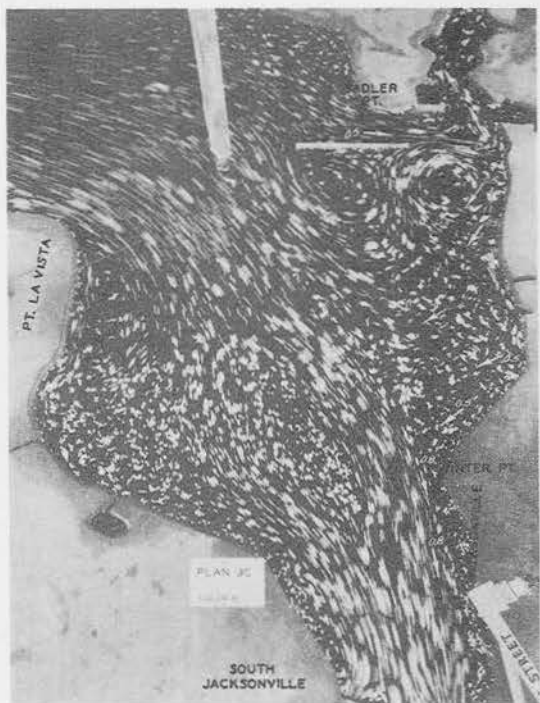
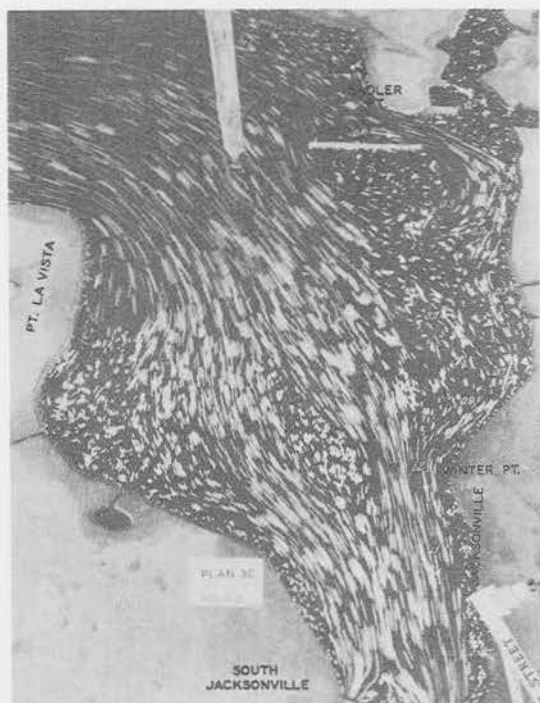






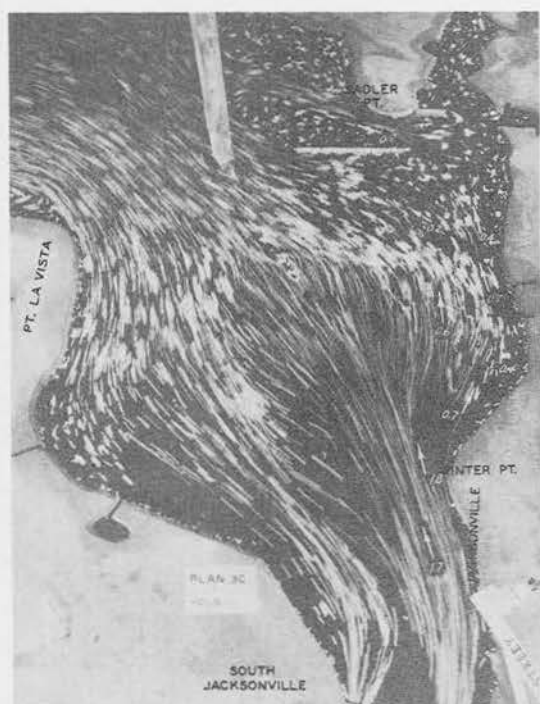
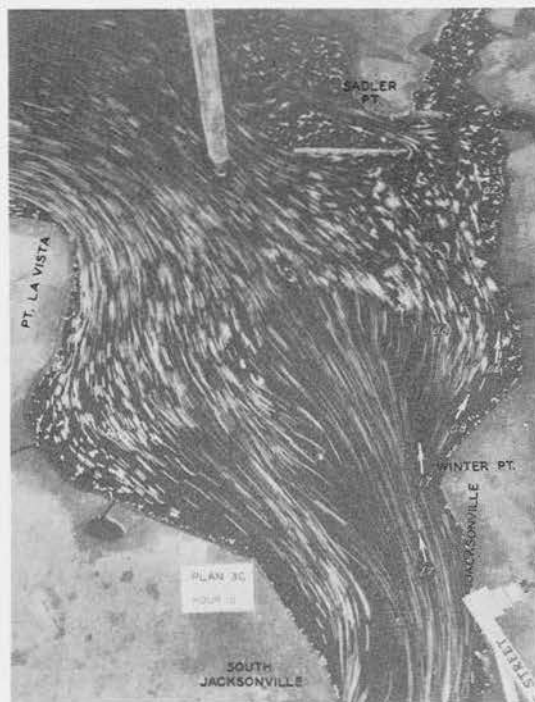
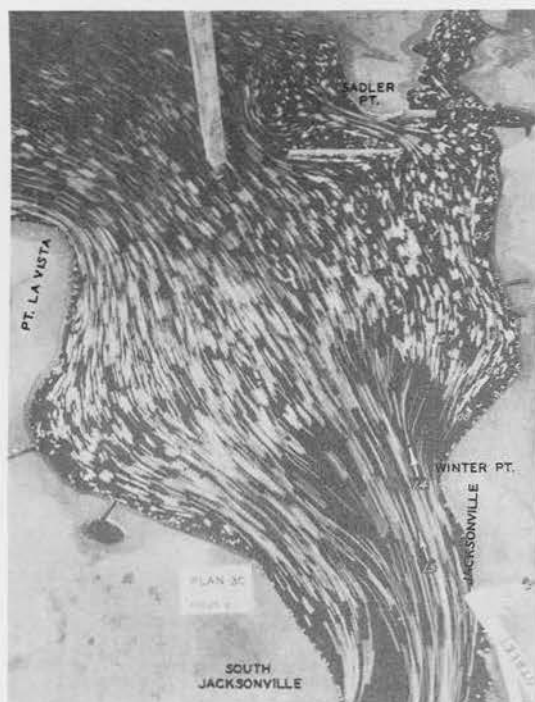


PHOTOGRAPH A22



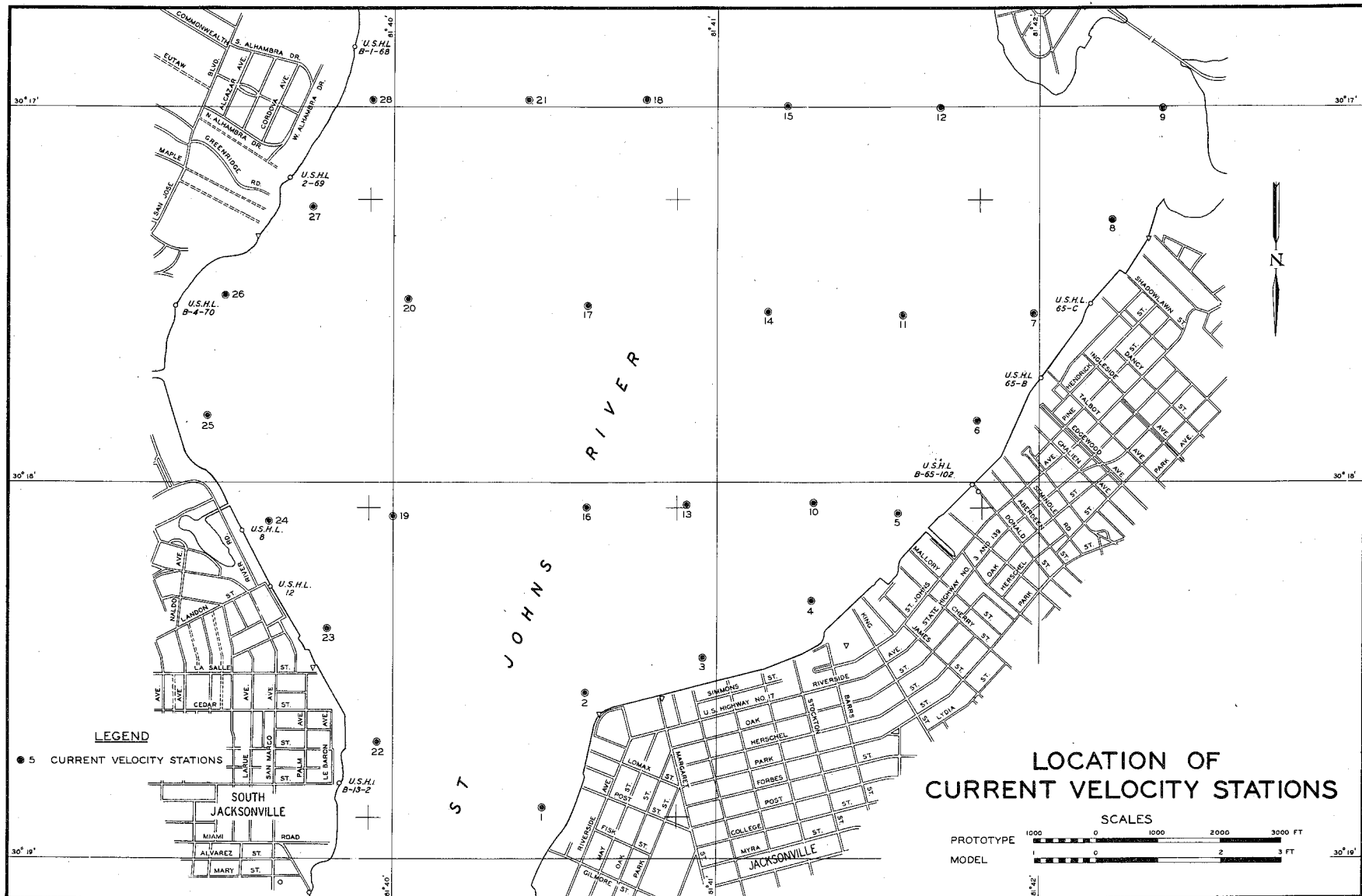
PHOTOGRAPH A 23

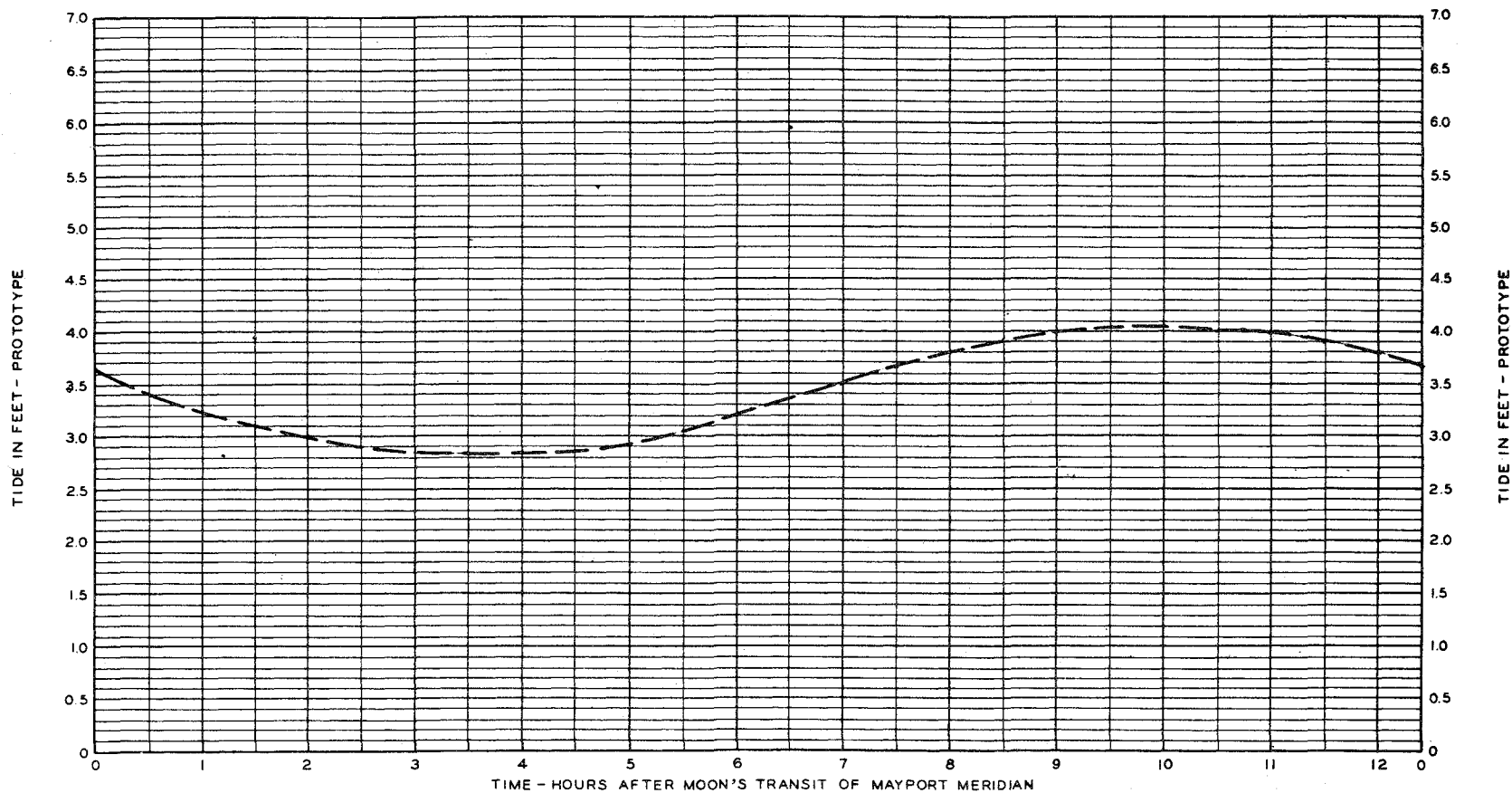




PHOTOGRAPH A24







NOTE: ELEVATIONS REFER TO MLW AT  
MAYPORT, FLORIDA.

THIS CURVE REPRESENTS TIDAL  
HEIGHTS FOR ALL PLANS TESTED.

TIDAL HEIGHTS AT  
ROSSELLE STREET GAGE